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Thomas A Edison Papers

A SELECTIVE MICROFILM EDITION

PART III
(1887–1898)

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A Note on the Sources

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Kennelly Notebook #4

This notebook covers the period November 1890-June 1891. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, lightning arresters, and the carrying capacity of copper wire. In addition, there are extensive notes and design drawings relating to electric traction, including motor tests (some of these experiments were conducted at the Edison General Electric works at Schenectady), determinations of the tensile strength of trolley wire, and notes concerning the set-up of the experimental track at the West Orange laboratory. Also included are notes regarding low-horsepower motors and 3- and 5-wire electric power systems, tests comparing Edison's experimental alternators and a.c. motors with those of Westinghouse, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "IV" and "1890-91." The book contains 170 numbered pages. Some pages were removed before the book was paginated. Numerous graphs, blueprints, tissue copies, and other items have been pasted into the book.

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No. IV.

Record Book

of

Observations, Calculations, and Data

compiled in the Galvanometer Building

Edison Laboratory, Orange N.J.

commenced 21st November 1890
completed 7th June 1891.

On the most suitable diameter for the cores of the phonograph motor's field-magnets. 3rd November 1890.

From measurements made on 3rd dept: 1889 vide Book III. p. 44, a sample phonograph motor making 7.33 revs: per second generated 1.485 volts or 0.2026 volt per rev: per sec. The number of wires counted all round = 1080

$$\therefore \varphi = \frac{2.026 \times 10^7}{1.08 \times 10^3} = 1.876 \times 10^4 -$$

The existing cross section of cores being 24 sq. cms, the inductions density is $187.6/24 \times 10^2 = 780$. say 1000 allowing leakage

(1) If the iron be of the usual casting material, an induction density of 3000 may be readily granted, or allowing as above for 22% leakage 2340 for useful flux. The cross section should therefore be 8 sq. cms. = 3.2 cms or 1.26" say 1¼" diameter.

(2) If the iron be mitis casting, then double this density may be used, the cross-section need only be 4 sq. cms. = 2.26 cm = 0.9" diam.

The winding for (1) of the same power will have as at present 135 turns to have 0.460 ω. The mean circumference being say $1.5" \times 3.142 = 3.71" = 0.31'$ 135 turns = 41.9'. (The present length is 105'). This is equivalent to 0.446/41.9 or 0.011 ω per foot. The nearest size to this is # 21 B.W.G. 0.0101 ω per foot or 45' for 0.446 ω.

The new winding will therefore be

45' of # 21 B.W.G. per limb = 0.446 ω
180' - - - - - field = 1.84 ω

To give the same exciting power with the existing weight of copper, which is $420 \times 0.007268 = 3.05$ lbs. on the field or 0.76 lbs: per one: we have to use a wire 442' long weighing 0.76 lbs and of $\frac{442}{105} \times 2401$ emil = 960 = # 21 B.W.G. = 3.253 ω per lb = 2.47 ω per limb = 250' = 700 turns.

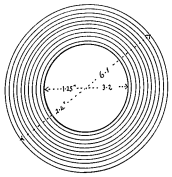
With # 19 B.W.G. whose res: is 1.096 ω per lb: there will be with 12oz 0.82 ω on each limb or 3.28 ω for all. The length being 184' per lb. there will be 1140' or about 450 turns. Hence with $\frac{450}{135}$, 3.33 times as many turns there will be 1.75 times as much resistance reducing the battery current about 40%.

With #20 B.W.G. whose res: is 2.27 ω per lb. the res: of 12 oz = 1.7 ω or 6.8 ω for the total field or 3.7 times as much as at present. The length will be 200' per limb = 670 turns = 5 times as many turns. The total gain in exciting power should thus be $\frac{5}{3.7} = 1.4$.

The diameter of the wire = 0.032" or covered 0.042" there will be 40 turns per layer and 17 layers. Mean diam $1.25 + 17(0.042) = 1.95" = 6.25' \times .05' = 400$ turns = 10 layers

mean diam $1.25 + 0.042 = 1.67 = 5.25' \times 0.44'$

Full size cross section of modified field limb Phonograph magnet.
Cast iron



Cross Section of core 8 sq. cms.
Diameter 1·25" 3·2 .
Ext: diam 2·4" 6·1
Total flux 18,760 useful
Total estimated flux 22,000
Induction density 2,750 .
Resistance of limb 0·82ω
Current in field with 2·2 volts at mt. 0·67 amp.
M.M.F. on one limb 250 A.T. per limb 192 , per pair 384.
Weight of wire on each limb 12g (3/4oz). Total weight of wire 3lbs (1360g)

Diameter of wire 0·042" #19 S.W.G.
= covered 0·057"
Turns per layer 31
Number of layers 9·5
Depth of winding 0·58" 1·45
Total turns 288.
Resistance of field 3·28ω.

Test 10th from 91 of a specimen field, first one wound to new model at Phonograph Works 0·042" wire cond. to 0·056"
8 layers of 36 turns each on each limb
Res: 0·77ω per limb or 3·05ω in all.

The best result will be given by #19 S.W.G. whose diam: is 0·042" or 0·057" incl covered = 31 turns per layer, and with 12 layers, the mean diam: = 1·25 + 0·69 = 1·93" = 6·07 circ: = 0·505' and 140' = 279 turns = 9 layers. The mean turn $\pi(1.25 + 0.51)$ = 5·53" = 0·46' = 300 turns = 10 layers. 0·57" incl. Mean turn $\pi(1.25 + 0.57)$ = 5·82" = 0·485' = 288 turns = 9·5 layers. There will then be 2·13 times as many turns as in the existing apparatus, and 1·75 times as much resistance, a gain of 1·28 or 28% in exciting power.

Determination of the Obach Galvanometer Single Ring Constants by electrolysis: 31st October 90. Observer A. J. Fraser.

The following are the results of a series of observations with two voltameters. One using silver electrodes in a 25% solution of $AgNO_3$, the other copper electrodes in $CuSO_4$ solution.

No. of Obt.	Voltameter	Weight of Plate before test	Weight of Plate after test	Transfer	Corrected Transfer	Time Duration of test, sec.	Transfer per second	Constant for Each Instrument	Current	Mean Deflection observed	Constant per amp.
1	Ag:	11·7470	11·01446	0·7024–	0·7026	300	0·002342	0·001118	2·09144	0·4018	0·1918
		11·8216	12·52446	0·7028+							
2	Ag:	10·9646	11·59448	0·6302+	0·63015	300	0·0021005	"	1·8785	0·36158	0·1925
		11·5239	11·1940	0·6299–							
3	Cu:	17·0838	16·8797	0·2041–	0·2039	300	0·0006796	0·0003279	2·07297	0·39639	0·1912
		17·5000	17·7037	0·2037+							
4	Cu:	16·2797	16·4580	0·1297–	0·1297	600	0·0002161	"	2·18410	0·41558	0·1903
		17·7037	18·1362	0·4325+							

Reduction of these values 0.1917 ± 0.000214

No.	Mean Ag. value	Weight.	Mean Cu Value	Weight.	General Mean		v	v^2	$\sum v^2$	$\sum pv^2$	γ_0
1	0·1918	(3)			90		0·0001	1×10^{-8}	5×10^{-9}		
2	0·1925	(3)			75	0·19170	0·0008	64×10^{-8}	192×10^{-8}		
3			0·1912	(2)	36		0·0005	25×10^{-8}	$\frac{284}{720} \times 10^{-8}$	146×10^{-8}	$0 \cdot 000214$
4			0·1903	(1)	3		0·0014	196×10^{-8}	196×10^{-8}		

During the last test the Troy ring deflection was observed as follows:

	Voltameter								Current	Deflection	Constant per amp.
4	Cu:								2·1811	18°25'	Tan: 0·1349
									0·2946121		per amp

If this current be reduced to the general mean = 0·1359 per amp. tan. 7°45'

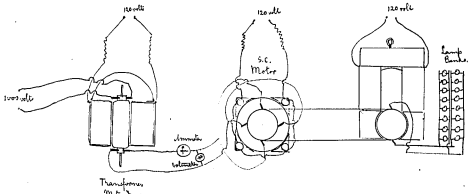
Test of the 20 volt quadripolar, bar-armatured Street Car Motor, whose design is recorded on page 72/73 Book III

The following observations were made with the field magnets all connected in series, and excited with different current strengths.

No. of Obs.	Current in fields	Revs: per min:	Revs: per sec:	P.D. at m.t.	Revs: per min: reduced to 15 volts emf	Revs: per sec: reduced to 15 volt emf	Peripheral Speed in kms @ 15 volts emf	
1	4·5	940	15·67	20	720	12·0	1914	On 2nd occasion
2	8·0	810	13·5	21·5	565	9·42	1503	On 1st occasion
3	10·0	524	8·73	21·0	374	6·23	994	- - -
4	5·0	1200	20·0	21·5	837	13·95	2225	- - -

The peripheral speed designed for was 2500 kmes at 3 amps: in the field at 15·7 revs: per sec. The actual speed is reckoned by the above to be at 3 amps 2870 kmes at 18 revs: per sec. In other words the reluctance of the circuit is 1·146 times its estimated amount.

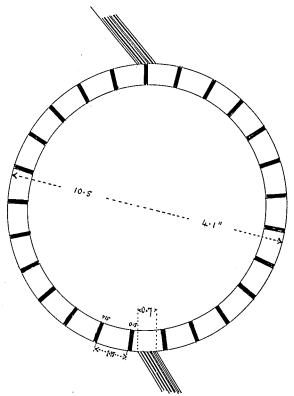
The next observations were made with a load on the motor. It was noticed that the machine heated considerably when operated without load in a strong field. The temps: on the armature rose to 130 °F after a run of one hour and to 175 °F after a run of three hours in ~~a~~ 9- amp. current field. This was principally due to the foucault currents generated in the armature shell or commutator bars of brass when the armature became nearly saturated. With a higher speed, and weaker field, the heat generated was distinctly less and took place principally in the bars themselves. They are evidently sufficiently wide to permit strong eddy currents.



No of Obs	Current in Field:	Current in motor	P.D. on motor	Energy in motor	Examples operated by dynamo	Amount per kmg estimated	Energy in dynamo at	Energy delivered @ 96%	Speed of motor revs: p. m.		
1	4·5	70	20	1500	not belted						
2	4·5	175	20	3500	belted				940		
3	4·5	480	16·4	7870	166	0·4	6640	7720	720		
4	4·5	520	16·45	8555	180	0·4	7200	8370	700		

This efficiency estimate is only very rough because the current and emf in the dynamo circuit were not observed.

Full sized section of commutator at right angles to its axis



Measurement of the permissable amount of electro-kinetic momentum, on the circuits terminating at commutator bars.

A commutator of 100 bars, and of dimensions represented, had its bars connected together in four, so as to make in effect a commutator of 25 bars. This commutator was fixed with its axis horizontal and projecting from a wooden frame holding 25 ring transformers of the pattern whose complete tests are recorded on p. 150 Book III. The bars were connected to the coarse wire coils of these transformers, arranged in continuous series, like a gramme ring. The fine wire coils were connected to a similar commutator with a separate pair of brushes. The measurements were made first with one and then with the other commutator with varying currents and speeds, simply to determine the limiting degree of sparking that could be permitted and the conditions of electro-kinetic momentum calculated to be existing at the moment of breaking each coil circuit at the brush.

If n be the no. of revs. of the brush-holder per sec., and r the radius of the commutator the peripheral speed will be $2\pi nr$ times, and since the brush face is 0.7 and the insulation 0.15 the time of short circuiting will be $0.55/2\pi nr$.

Fine wire commutator

No of Obs	Current in machine	Current in each coil	Inductance of each coil	Time constant of each coil	Speed of Armature per min.	Revs. per second n.	Peripheral Speed $2\pi nr$	Time of short circuit seconds	$\epsilon_2 - \frac{1}{2}$ Instantaneous Current c_2	$c_2 - c_1$	$L(c_2 - c_1)$ volt. seconds	Spark
1	1·1	0·55	0·01463	0·01308	740	12·33	406·8	0·00135	0·495	1·045	0·0684	moderate
2	1·7	0·85			390	6·5	214·5	0·002565	0·70	1·55	0·07176	bad
3	1·0	0·5			880	14·7	485·0	0·001134	0·46	0·96	0·0446	medium
4	1·2	0·6			675	11·25	371·1	0·001483	0·536	1·136	0·0526	Inaudible

The observations were then repeated on the coarse wire commutator as follows:-

No Obs	Current in machine	Current in each coil	Inductance of each coil	Time constant of each coil	Speed of Armature Revs. per min.	Armature Revs. per sec.	Peripheral Speed $2\pi nr$	Time of Short circ. seconds	$\epsilon_2 - \frac{1}{2}$ Instantaneous current c_2	$c_2 - c_1$	$L(c_2 - c_1)$ volt. seconds	Spark
1	5·5	2·75	0·001806	0·01480	960	16·0	527·9	0·001016	2·566	5·316	0·009604	just bearable
2	6·8	3·4			660	11·0	363·	0·001518	3·06	6·46	0·01167	" "
3	8·3	4·15			468	7·8	257·4	0·002138	3·577	7·727	0·013956	" "
4	9·7	4·85			400	6·67	220·1	0·00250	4·110	8·960	0·01619	" "
5	0·9	0·45			780	13·0	428·9	0·001283	0413	0·863	0·00156	barely perceptible
6	2·0	1·0			360	6·0	198	0·002778	0·829	1·829	0·00330	" "

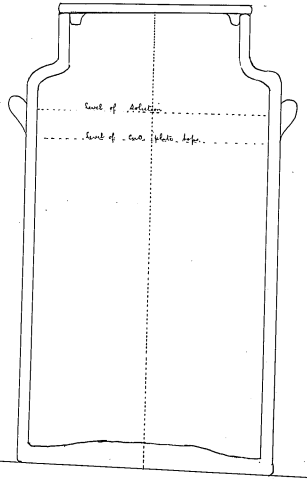
The maximum permissable momentum or impulse for the coarse wire coils was 526 kilomatic ampere or $\frac{1}{20}$ volt-second, apparently independent of the speed, for the coarser wire coils it was 160 kilomatic ampère, apparently diminishing with speed

Mechanical Data of Cell.

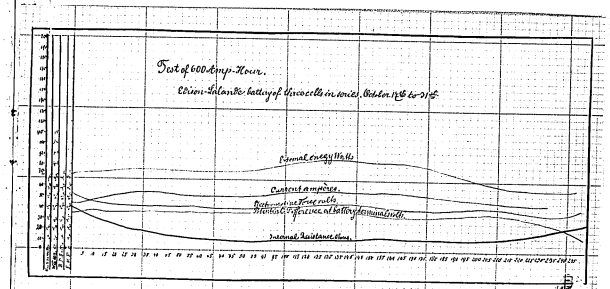
External space occupied when charged & set up 21·4 X 20 X 38 high
8·½" X 8" X 15" "
volume - - - - - 1626 c.c.
99·2 c.in.

Weight of cell (stone ware jar)		8 lbs.	6½ oz.	5813 gms.
Volume of liquid contents.	5500 c.c.			
Weight of " " @ 1·25 =	6875 gms	15	2½ "	6875
" " two zinc plates	792 gms	1	12 "	792
" " " copper oxide plates in one frame		2	0 "	907
" " one copper frame.			5½ "	156
" " porcelain cover			10 "	284
" " Total weight charged		28 · 4½ "		12827

Area occupied by each charged cell 68 sq. in. 428 sq. cms ☐



Vertical section of 600 amp. hr. jar through the axis 1/2


Test of 600 Amp-Hour.
Edison-Falconbridge battery of 10 cells in series, October 1915 to 1916
Normal Energy Watts
Current amperes
Normal Resistance ohms

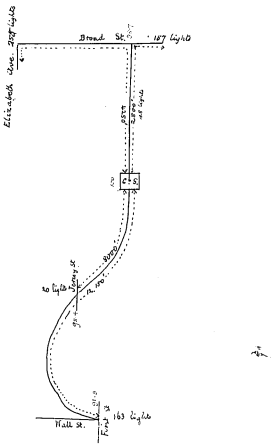
Test of 3 Edison Lalande 600-Amp: hour cells joined up in series and working a phonograph. From October 17th to October 31st 1920.

Date	Time	Hours	E.M.F.	P.D. battery	P.D. motor	Ohmage	current	Phonograph Speed	Watts
		hrs. mins							
17th Oct.	13·35	0	2·676	1·838		0·428	2·14	145	3·9
	18·05	4·30		1·802		0·400	2·00		3·6
18th "	8·05	4·30		1·790		0·47	2·37		4·24
	11·20	7·45		1·774	1·774	0·43	2·20	142	3·9
19th "	17·05	12·30			1·774	0·43	2·2	142	3·9
20th "	8·10	17·30			1·746	0·424	2·2		3·8
	12·00	22·20			1·684	0·53	2·7		4·5
21st "	8·30	37·50	2·116	1·824		0·47	2·35		4·3
22nd "	9·15	62·35		1·806		0·47	2·35	140	4·2
23rd "	8·35	85·55		1·810		0·50	2·5	0	4·5
	11·25	88·45		1·818		0·43	2·15	130	3·9
	17·00	94·20		1·850		0·443	2·15		4·0
24th "	8·15	109·35		1·840		0·49	2·45	130	4·4
	12·00	113·20			1·774	0·575	2·88		5·1
25th "	8·30	133·55	2·132	1·756		0·445	2·23	134	3·9
	13·30	138·55		1·732		0·5	2·5		4·3
	17·45	143·05		1·782		0·437	2·18		3·9
27th "	8·30	143·05	2·084	1·752	1·590	0·520	2·60	144	4·5
	13·30	148·05		1·700		0·51	2·55	142	4·3
	18·00	152·35		1·750		0·47	2·35	136	4·1
28th "	8·30	167·05	2·060	1·730	1·670	0·45	2·25	148	3·9
	18·00	176·35		1·782		0·39	1·95		3·4
29th "	9·00	191·35	1·952	1·706	1·652	0·38	1·9	150	3·2
	17·15	199·50		1·706	1·654	0·39	1·95		3·2
30th "	8·30	215·05	1·924	1·586	1·462	0·41	2·05		3·1
	17·50	224·25		1·578	1·528	0·36	1·8	126	2·8
31	8·30	239·05	1·626	1·044	0·912	0·595	2·92	0	3·0
	12·30	243·05							
	16·30	243·35	1·452	1·004		0·42	2·1	90	2·1

The battery thus operated the phonograph about 10 days in all. Chipping was occasionally practised also to imitate actual service, but probably the work done in chipping with practically worked instruments would exceed that here given, so that 10 days would be an outside limit. The sp.g. of the solution before starting was 1·225 and at close 1·36. One zinc had actually been consumed till it broke near the surface. The weight of zinc in the battery at ~~started~~ was 40 @ 1160 grs. of 120g grms and ~~sold~~ was 66 @ 1372 - 1960 - Loss 26 242 - 754

Starting Weight of Zinc	Closing Weight of Zinc	Loss	Mean Current	Amp. Hrs.	Calculated Loss	Discrepancy
316g	120g	1960	2·25	2·24 x 243·5 = 550·3	3 x 673·6 = 2020·8	60·8 grms.

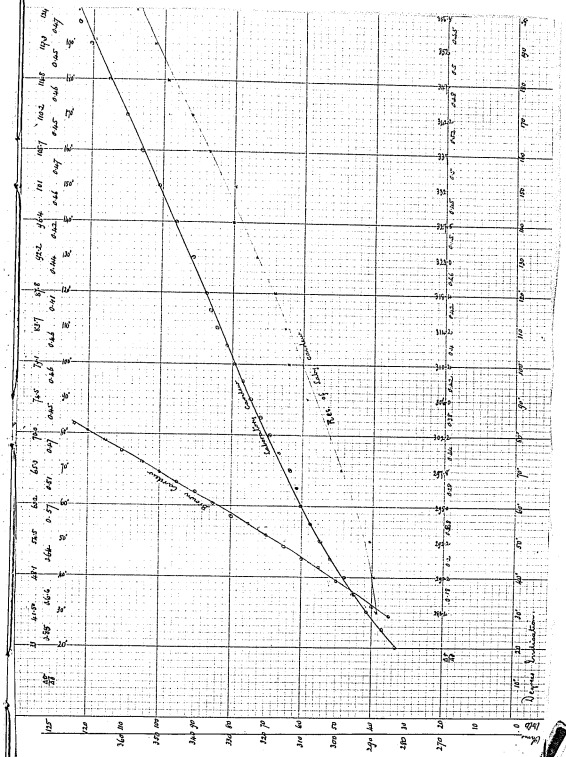
Measurements made with delicate fuses of lead foil strip between mica sheets. Nov. 90.



163	Lights	operated at	1st & Wall St	a distance of 12,150'
20	-	-	Jersey St	- - 8000'
187	-	-	Broad St	- - 2800'
255	-	-	Elizabeth Ave	- - 4250'
48	-	-	Feeder to Broad	- - -
643	-	-	on two feeders.	

Ammeter indicates over 35 amperes

Size of feeders 0.200" # 6 B.W.G. = 2.5×10^{-4} ohms per foot.



Determination of Alternating Voltages by Mr Davis at the Central Station, and different points of the conductor systems in N.S. 5th & 6th Nov. 1820.

Laboratory Gardeur voltmeter

Res. of unit 288 warm

Degrees Ind.	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	190°	200°
Continuous volts	33·2	41·6	47·8	53·3	60·1	63·8	69·2	74·5	79·4	84·5	87·6	91·6	96·0	101·0	106·	110·3	115	120·6	126
ΔV	8·4	6·2	4·5	5·8	3·7	5·4	5·3	4·9	5·1	3·1	4·0	4·4	5·0	5·0	4·3	4·8	5·6	5·4	
$\Delta\theta/\Delta\theta$	0·84	0·62	0·45	0·58	0·37	0·54	0·53	0·49	0·51	0·31	0·40	0·44	0·50	0·50	0·43	0·48	0·56	0·54	
Current Watts	91·5	101·36	12·0	13·36	14·36	15·11	16·0	17·16	18·	19·0	19·36	20·0	20·36	21·36	22·16	23·	23·36	24·	
Res.	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	0·0278	
	0·2353	0·2362	0·2371	0·2385	0·2322	0·2310	0·2332	0·2317	0·2307	0·2342	0·2342	0·2367	0·2378	0·2400	0·2407	0·2382	0·2397	0·2387	
	0·123	0·1243	0·1253	0·1268	0·1222	0·1212	0·1232	0·1217	0·1207	0·1242	0·1242	0·1267	0·1278	0·1300	0·1307	0·1282	0·1297	0·1287	
	264·2	268·6	269·3	269·7	329·7	329·9	330·3	329·4	328·1	310·3	318	322·6	325·0	324·6	337·3	340	342·3	342·9	345

Brown Gardeur Voltmeter

Calibrated 28th October 1820.

Volts (continued)	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110·5	115	120	124
Degrees rotation indicated θ	29	31·8	35·8	38·8	42·6	45·2	48·3	51·9	55·0	57·5	60·5	63·8	66·7	69·4	72·0	75·1	78·0	80·8	82·5
$\Delta\theta$	2·8	3·2	3·9	3·0	3·6	2·6	3·1	3·6	3·1	2·5	3·0	3·3	2·9	2·7	2·6	3·1	2·9	2·8	1·7
$\frac{\Delta\theta}{\Delta V}$ $\frac{\Delta\theta}{\Delta E}$	0·56	0·64	0·78	0·60	0·72	0·52	0·62	0·72	0·62	0·50	0·60	0·66	0·58	0·54	0·52	0·62	0·58	0·56	0·34
	1·76	1·56	1·32	1·22	1·85	1·61	1·89	1·66	2·0	1·67	1·67	1·72	1·85	1·92	1·64	1·72	1·78	2·00	

Res. of instrument warm 3574 Add 10 f. su Ench II. f.102 = 3683 5m 72°
1st coil 10714 13289 380 " 50°
2nd coil 4291 5649 378 " 44
3rd coil 7026 12645

Mr Davis observations.

H.P.S. Gardeur

Date	Position	Reading	Resistance	Multiplying power	Volts	Reading	Res. in circ	Multiplying power	Volts		
								Brown Gardeur			
Nov. 5th	C.S.	44°	7500	29.000	57·6	12·14	·35	7500	450	289·3	1212·	(1)	(2)
		45°	7000	29.670	59·6	1178	38	7000	474	291·7	1381·75	1175	1200
		50°	6000	26.79	64·4	1172	54	6000	564	292·8	2165·1223	1192	
		72°	4000	18·28	105	1150	12·1	4000	884	318·9	13·55 1195		
6th	C.S.	43·5°	7500	29.000	56·7	1191	33	7500	423	284·3	2733 1194		
		45°	7000	29.670	59·6	1178	37	7000	465	289·5	25·18 1171	1175	1174
		51°	6000	26.79	64·7	1154	47	6000	559	291·6	21·58 1142	1175 - 100	
		72°	4000	18·28	105	1186	118	4000	97	317·6	13·60 1183		
Jersey	Jersey St	43°	7500	29.000	55·8	1177	33·5	7500	438	285	27·32 1197		
		44°	7000	29.670	57·8	1137	38	7000	469	289·8	25·16 1177·5	1118	1176
		48·5°	6000	26.79	60·3	1097	50·5	6000	526	290·3	21·67 1188		
		47·5°	4000	18·28	96·5	1089	113·5	4000	851	315·8	13·67 1163	1156 - 98·36	
2nd Wall	1st Wall	40·5	7500	29.000	52·5	1098	30	7500	401	285·4	2701 1121		
		42	7000	29.67	50·2	1066	34	7000	461	289·2	25·20 1112	1036	1102
		45·5	6000	26.79	60·3	1086	43	6000	580	290·9	21·64 1082	1050 - 91·9	
		62	4000	18·28	97·5	987	100	4000	781	310·2	13·91 1101		
	Exec Wall	42·5	7500	29.000	56·3	1153	35	7500	465	289·3	26·93 1206·5		
		44·4	7000	29.67	57·9	1137	38	7000	469	289·8	25·15 1177	1124	1178
		49	6000	26.79	66·0	1105	49	6000	594	292·0	21·88 1162	1160 - 98·7	
		68·5	4000	18·28	98·4	1111							
	Broad	43·5	7500	29.000	56·4	1159	35	7500	449	289·3	26·93 1207		
		44·5	7000	29.67	58·8	1157	38	7000	465	289·9	25·15 1177	1138	1173
		49·5	6000	26.79	66·7	1120	51	6000	583	292·5	21·82 1186	1161 - 98·7	
		68·5	4000	18·28	98·4	1111	111	4000	801	314·6	13·72 1154		

Description and Data of an Eickemeyer Street Car and Motor, from a report by Mr. J. H. Vail to the Engineer-in-Chief dated 8th Nov. 90.

Motor Series wound bipolar drum armature Eickemeyer winding
Speed 100 revs to 180 revs per min 1.67 to 3 revs per second
Periphaval speed 314 to 565 ft per min = 5.25 to 9.4 ft per sec
Velocity ratio of armature to car axle ~~1~~ 1, and speed of car = 0.0536 n miles per hr. where n = revs per min
Number of sections in armature 70, each of 8 turns. Wire = .560
Breadth of drum 17" diam: of drum 12" (core measurement)
Cross section of core 204 sq. in (1316 sq. cm)
Wire # 9 B+S 0.114". Res: between brushes 0.7Ω. 2 layers.
E.M.F. of supply 250 volts. Power 15 HP = 11300 Watts. Current 45 amp
Density of current 600 amil per amp.
Maximum useful flux $240 \times 10^6 / 1.67 \times 560 = 25.660.000$
Density of flux in ~~iron~~ body including insulation space 19.580 ?
Field coil consist of 900 turns of #8 B+S 0.1285" in 2 sections
Resistance 4.0Ω = 64.00' = 7.1' per turn? . Where sections in multiple res: of field = 1Ω.

The motor shaft is connected at each end to crank discs through universal joints. Crank pin radii in these discs make angles of 90° with each other. Pin radius = 4". Connection is made directly from these discs to the car wheels 18" in diam: by connecting rods 17" long. Both crank and wrist pins have ball bearings.

The weight of the car on which this motor was placed was as follows:- Motor 21400 lbs.
Truck 31470 .
Car body 1700 . 7570
8 persons 1130 8700

The car was very short and carried one motor. The track was about ¼ mile long, practically level except one short grade of 3%, and was straight with exception of one curve of about 50' rad: also on a slight grade. The day was wet, the rails clean and moist. There was one trolley wire, and the rail return was used. Drop in conductors about 5 volts. The following readings were taken at 10 second intervals.

	Speed											Hydraulic brakes			Load	full load		
No: of Obs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Volts	250	220	220	210	220	220	220	220	210	200	210	210	260	250	240	220	210	200	240
Ampere	35	25	20	20	20	22	25	25	25	25	30	40	35	25	15	15	20	20	22
Watts	8750	5500	4400	4200	4400	4840	5500	5500	5250	5000	6300	8400	9100	6250	3600	3300	4200	4000	5280
Joules	87500	142500	186400	228600	273000	319200	374000	429200	481250	531250	584250	642250	706350	768600	819600	868200	910200	950200	1027700

Power estimated to be wasted in armature 425 Watts = 252.000 Joules
" " " field 900 " .

Haulage @ 25 lbs. per ton = 8.450 ft lbs = 115.000 Joules
Lift @ 20 feet = 174.000 " = 232.000 "
Acceleration to 7.5 mph = " = 22.000 "
Estimated Total useful work done 369.000

Power absorbed 1.027.700 Joules, developed in armature 772.700 = 75%
" " usefully 369.000 = 36%

Record of Experiments made at Schenectady Works 10th – 16th November 1890.

On arrival at Schenectady 10th Nov. the experimental car with motor #1 (128 dia: arm:) and two 5" magnetic link belts was taken out on the track. It ran successfully on the level, but generally stopped on the 5% grade, the belt then slipping on the small pulley. The p.d. at car was about 500 volts and the current about 8 amperes. The weight of the car complete was 10,950 lbs or with 4 men 11,200 say = 5.75 tons. The limiting pull on the two belts together was therefore 5/100 × 11,500 = 575 lbs. with 50×8 = 400 ampere-turns in each small pulley. On one occasion however the car succeeded in mounting the grade (see Book III p. 123).

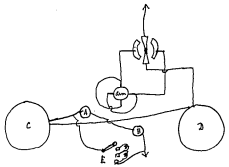
In a subsequent trial armature #1 abraided the pole heads, and became badly damaged. It was taken out and replaced by armature #2. (128 dia) radially connected with 4 brushes of carbon.

The belts did not make more than two contacts with the surfaces of the small pulleys. To increase the surfaces in contact, they were ground on an emery wheel to the contour of the small pulley. An experiment was then made to ascertain the effect of this upon the traction. With 800 ampere turns in one pulley, the increase of traction was about 20% with the ground links over the flat links in belt.

The car was again tried on the track with the #2 armature and the ground belts. On this occasion there was a greater pull at the small pulleys, but the belts now slipped on the large pulleys. This was traced to bad grounds in each large pulley and one clutch. The car was therefore taken back to the shop, the clutches cut out of circuit and screwed fast, while the large pulleys were rewounds with rubber covered wire 7 turns in each groove or 114 turns in all on each large pulley. The small pulleys were also rewound with 9 layers of 6 turns = 54 turns of double cotton covered wire in each groove or 270 turns on each pulley. Under these conditions twenty amperes was passed through them for ten minutes with a resulting temperature just high enough to char the cotton slightly. The res: of #2 arm: across brushes 1·220 ohs.

The car was next raised off the floor by jacks, and breaks applied to each driving wheel in turn. The current was shunted from the small pulleys by the resistance box. With 8 amperes = 2160 A.T. on each small pulley and 1125 A.T. on each large pulley, the break torque was 100 lbs weight at 5¼" rad: on one wheel, just slipping on the large pulley, and with 14 amperes = 3780 A.T. on each small pulley or 1960 A.T. on each large pulley the break torque was 111 lbs weight at 5¼ 3/4" radius. Total equivalent pull at each 760 lbs.

The car was then lowered on the track and attached to a beam by chains through a dynamometer. On releasing the small pulley shunts, the current went up to 56 amperes on the first trial (volts not read) and the indicated pull 1900 lbs. no slip. On the second trial, after a pause to let the small



A B Small pulleys
C D Large "
E Shunt switch.

pulleys cool, there was some slip on the large pulleys, the current being 30 ampères the p.d. at motor terminals 360 volts, p.d. on pulleys 100 volts. Power absorbed by four pulleys 3000 Watts = 4 H.P. The dynamometer pull was 1400 lbs, allowing for index error say 1500 lbs. The resistance of each small pulley = 0·8 ω cool total resistance of all four pulleys warm 3.3 ω.

This armature was then exchanged for the 512 dia. #3 armature having 2·5" of C.S. wire 0·020" between section and commutator. A test of this armature with 4 carbon brushes was then made under load. The resistance of this armature between brushes is 1·35 ω cool. The motor was belted to a dynamo and the speed gradually raised. The sparking was not excessive at 600 revolutions (full speed) with 45 ampères and 500 volts = 22,500 Watts absorbed in armature but was greater than would be practically desirable. The maximum load however anticipated at this speed is 20 or 25 ampères. This result shews a considerable improvement due no doubt to subdivision of the sections and german silver connections.

The speed of #2 armature was 258 revolutions at 470 volts p.d = 274 at 500 volts, The calculated speed in design was 230, but the entire has been increased from 1·68 to 2·0 by boring out the field an extra 1/8". If this space could have been saved, the speed expected would have been at 500 volts p.d. 0·84 × 274 = 230. revs.

Measurement of the coefficient of friction between smooth cast iron and smooth wrought iron 17th Nov. 20.

The coeff. when dry) was	0·156	by one method of measurement	} 0·158
	0·160	– another second –	
. . . wet .	0·199	. 1st method	} 0·205
	0·211	. 2nd .	
. . . oiled .	0·070	. 1st .	} 0·070
	0·070	. 2nd .	

On the diameter of suspended copper wire whose inductance per mile of 5280 feet shall be 10^4 cms.

From the formula $l = \frac{\mu}{2} + 2 \log_e \frac{2h}{a}$

We have $160,930 \left(0.5 + 2 \log_e \frac{2h}{a}\right) = 1\,000\,000$

$$0.5 + 2 \log_e \frac{2h}{a} = 6.215$$

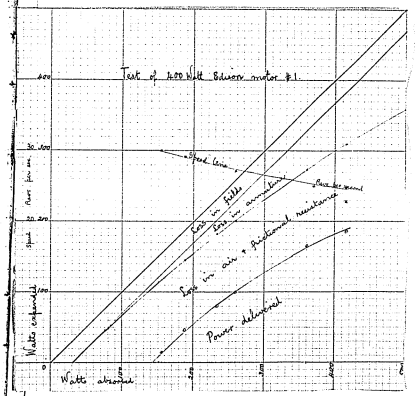
$$2 \log_e \frac{2h}{a} = 5.715$$

$$\log_e \frac{2h}{a} = 2.858$$

$$\frac{2h}{a} = 17.4$$

$$h = 8.7\,a.$$

No. of Obs.	P.D. on motor	Ohmich	Current in motor	Energy in motor	Energy in armature	Calculated Resistance in armature	Difference	Revs. per min.	Revs. per sec.	drop in armature	p.d. in armature
1	122.8	0.047	0.245	30.7				1 -			
2	122.8	0.235	1.226	150.5	120.14	6.7	183.7	1800	30	6.867	115.9
3	124.6	0.245	1.274	154.8	124.7	7.5	147.2	1800	30	7.238	117.76
4	120.8	0.298	1.558	187.8	157.7	12.0	1145.7	1752	29.2	9.17	111.63
5	120.0	0.370	1.930	231.6	201.5	19.9	181.6	1704	28.4	11.80	108.2
6	119.2	0.415	2.165	258.1	228.0	25.8	202.2	1632	27.2	13.44	105.76
7	117.0	0.590	3.075	360.1	330.0	56.2	273.8	1500	25.0	19.23	97.17
8	117.7	0.675	3.522	414.5	384.4	75.2	309.2	1488	24.8	22.94	94.76
9	117.6	0.600	3.130	368.1				1488	24.8		



½ HP Test of New Edison Motor First Trial. 8th Nov. 90. (11)

The machine was floated in the tank and connected by flexible shaft with the Edison 250 Watt motor model that usually stands in the Laboratory. The resistances of the armatures between brushes = 0.90 ohms = 7460 Mhot. Inductance of armature separated from field 382.4 kilometres. Inductance of a single coil = 15.42 kilometres. Resistance of field 559 ohms cold and 5740 Mhot. Weight of motor 27 lbs.

	Revs. per minute	Scale Reading	Torque cm. grms.	Energy delivered	Energy lost in Friction	Energy lost in armat.	Total	Electrical efficiency	Mechanical efficiency	
1		–	–	–	–	–	–	–	–	Field excited.
2	3·863	–	–	–	113·7	67	150·5	0·758	–	Running light
3	3·759	50 on 14·7	835	15·44	101·8	38·5	154·9	0·757	0·099	Driving dynamo arm. light
4	3·822	200 on 10 + 50 on 11	2550	45·91	99·8	12·0	187·8	0·776	0·244	Driving under load
5	3·810	200 on 20 + 200 on 21	4560	79·86	101·7	19·9	231·6	0·784	0·345	– – –
6	3·888	200 on 30 + 200 on 31 + 50 on 77	5885	98·68	102·5	25·8	258·1	0·783	0·382	– – –
7	3·887	200 on 40 + 200 on 41 + 50 on 84	10,700	165·0	108·8	56·2	360·8	0·761	0·458	– – –
8	3·821	200 on 50 + 200 on 51 + 50 on 91	12,160	185·9	123·3	75·2	414·5	0·746	0·448	– – –
9			11,850							after one hour.

The number of wires all round the armature being 2058, and the emf per rev $3·837 \times 10^9$ the flux through the armature is $1·864 \times 10^5$. The cross section of iron being 12.9 gives a mean density of 14,450

Magnetic measurements with motor 18th Nov. 90.

No. of Obs	Source of EMF	EMF at brush	Coupling	Q	Mean thro' div.	q per div.
7	3 C.C. at 25°	4·2975	1	$4·2975 \times 10^{-7}$	171·7	$2·503 \times 10^{-9}$

	Obstack.	Current thro' field magnet	No of turns	Mean throw	Rev. added	Rev. of galvt.	Q	$2\pi\phi$	No. of turns n	ϕ	Remarks
	0·037		3	251	0	52·50	$6·282 \times 10^3$	$3·298 \times 10^5$	5	329,800	Flux thro' centre of field magnet
			3	73·7	0	–	$1·844 \times 10^3$	$9·680 \times 10^4$	5	96,800	Flux through lower part of armature
			3	75·3	0	–	$1·885 \times 10^3$	$9·896 \times 10^4$	5	98,960	– – upper – –

The total useful flux by this method is $1·957 \times 10^5$; by the preceding $1·864$. Taking the latter, the leakage loss is $1·431 \times 10^5 = 196\%$ and the ratio r is 1·77.

When the motor is running light, and the machine is suddenly disconnected from the mains the armature comes to rest in 2·8 seconds. When the brush only is lifted, it comes to rest in 7·5 seconds.

The radius of gyration of the armature is about 6 cms, and its mass 3450 gms. Its moment of inertia may therefore be estimated at 123,000 cm²gms. $\omega = 30 \times 2\pi = 188·5$ $\omega^2 = 35,532$. $\frac{1}{2}I\omega^2 = 2·173 \times 10^9$ ergs = 217 Joules. To bring the armature to rest in 7·5 seconds requires an expenditure of nearly 30 Watts average retarding activity.

$i_1 = \frac{220r^2 + 88r + 8.8}{12r^3 + 8.7r^2 + 1.52r + 0.04}$; $i_2 = \frac{99r + 22}{(\quad)}$; $i_3 = \frac{220r^2 + 99r + 11.0}{(\quad)}$

$v_1 = \frac{1100r^2 + 440r + 44.4}{(\quad)}$ $v_2 = \frac{19.8r + 4.4}{(\quad)}$ $v_3 = \frac{88r^2 + 39.6r + 4.4}{(\quad)}$

$v_1 - v_2 = \frac{1100r^2 + 24.2r}{12r^3 + 8.7r^2 + 1.52r + 0.04} = 2$

$\therefore \quad 55r^2 + 12.2r = 12r^3 + 8.7r^2 + 1.52r + 0.04$

$12r^3 - 46.3r^2 - 10.68r + 0.04 = 0$

$r^3 - 3.85833 - 0.89r + 0.003333 = 0$

$r = 0.003685 = 3.685 \times 10^{-3}$

$r^2 = 0.00001358 = 13.5792 \times 10^{-6}$

$r^3 = 0.00000050 = 50.029 \times 10^{-9}$

$12r^3 = 0.000.0006$

$8.7r^2 = 0.000.118.1+$

$1.52r = 0.005.601.2$

0.04

$0.005.719.9$

$220r^2 = 0.002.987.4$

$88r = 0.324.28$

8.8

$9.127.267$

$i_1 = 199.634$

$i_2 = 4.89.170$

$v_1 = 99.817$

$99r = 0.364815$

$22.$

22.364815

$i_3 = 248.640$

$v_2 = 97.834$

$220r^2 = 0.002.987.4$

$99r = 0.364.815$

11.0

$11.367.802$

$i_3 = 248.640$

$v_3 = 99.456$

$i_1 + i_2 + i_3 = 937.444 \times 0.003686 = 3.45455$ from $55r = 51.5455$ v_1

$i_2 + i_3 = 737.810 \times 0.003685 = 2.7188$ 2.7189 48.8267 v_2

$i_3 = 248.640 \times 0.003685 = 0.9162$ 0.9162 47.9105 v_3

$i_1 + i_2 = 688.804 \times 0.003685 = 2.5382$ 51.5455 v_1 2.5382 49.0073 v_2

$i_1 = 199.634 \times 0.003685 = 0.7357$ 0.7357 48.2716 v_1

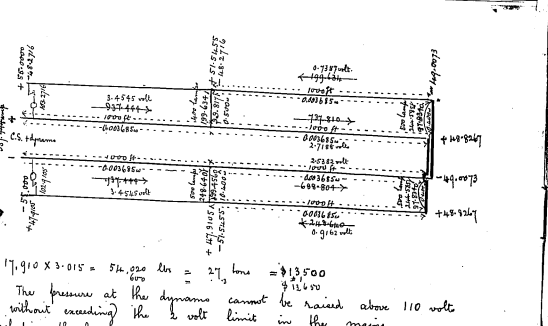
(+) 51.5455 v_1 (+) 48.8267 $v_{2(+)}$ (+) 47.9105 v_3

(−) 48.2716 v_1 (−) 49.0073 $v_{2(-)}$ (−) 48.5455 v_3

99.8171 97.8340 96.4560

The res: 0.003685 being of 1000 ft, the res: per foot = $0.000.003.685$ ω

requiring $\frac{18.0 \times 10^6}{3.685} = 2.985$ million cmils per ft. + 6000 ft = 17,910 million cm.ft.



$17,910 \times 3.015 = 54,020$ lbs $= 27$ tons $= \$135.00$

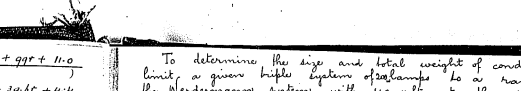
$\$11.480$

The pressure at the dynamo cannot be raised above 110 volt (without exceeding) the 2 volt limit in the mains.

Including the lamps at the Station, about to be lit the p.d. varies from 103.2716 volts to 97.8340 or 2.7189 ± 100.5528 the mean p.d. in range of 2.5%

Three lamps take 2000 ft of 100,000 = 200 million cmils = 608 lbs of copper.

To determine the size and total weight of conductors which shall limit, a given triple system of $\frac{2m}{3}$ lamps to a range of 2 volts p.d. on the Werdermann's system, with 110 volts at the dynamo.



Let the current be i_1 thro' $\frac{2m}{3}$ lamps & $m\omega$, i_2 thro' $\frac{2n}{3}$ lamps or $n\omega$, and i_3 thro' $\frac{2p}{3}$ lamps or $p\omega$

Then

$$\left.\begin{aligned} r_1(i_1+i_2+i_3) &+ i_1 m + r_1(i_1) + r_2(i_2+i_3) + r_3(i_1+i_2+i_3) - E = 0 \\ r_2(i_1+i_2+i_3) + r_1(i_1+i_2) &+ i_2 n + r_2(i_2+i_3) + r_3(i_1+i_2+i_3) - E = 0 \\ r_1(i_1+i_2+i_3) + r_1(i_1+i_2) + r_2(i_3) &+ i_3 p + r_3(i_1+i_2+i_3) - E = 0 \end{aligned}\right\}$$

Three simultaneous equations suffice for the determination of i_1 i_2 + i_3.

To abridge the computation let $r_2 = r_1 = r_2 = r_3 = r$ Then the determinant.

$$\begin{array}{|ccc|} 4r+m & 3r & 2r = E \\ 3r & 4r+n & 3r = E \\ 2r & 3r & 4r+p = E \end{array}$$

Set $\frac{m}{r} = \mu$ $\frac{n}{r} = \nu$ $\frac{p}{r} = \varpi$ and $\frac{E}{r} = c$

$$i_2 = \frac{c}{\Delta}\begin{vmatrix} 4+\mu & 1 & 2 \\ 3 & 1 & 3 \\ 2 & 1 & 4+\varpi \end{vmatrix} \quad ; \quad i_1 = \frac{c}{\Delta}\begin{vmatrix} 1 & 3 & 2 \\ 4+\nu & 3 & 3 \\ 1 & 3 & 4+\varpi \end{vmatrix} \quad ; \quad i_3 = \frac{c}{\Delta}\begin{vmatrix} 4+\mu & 3 & 1 \\ 3 & 4+\nu & 1 \\ 2 & 3 & 1 \end{vmatrix}$$

and $\Delta = 12 + 7\mu + 12\nu + 7\varpi + 1\mu\nu + 1\mu\varpi + 1\nu\varpi + \mu\nu\varpi$

$\therefore \quad i_1 = 2 + 2\nu + \varpi + \nu\varpi \times \frac{c}{\Delta}$ and pressure $v_1 = 2m(2 + 2\nu + \varpi + \nu\varpi)\frac{c}{\Delta}$

$i_2 = \mu + \varpi + \mu\varpi \times \frac{c}{\Delta}$ $v_2 = n(\mu + \varpi + \mu\varpi)\frac{c}{\Delta}$

$i_3 = 2 + \mu + 2\nu + \mu\nu \times \frac{c}{\Delta}$ $v_3 = p(2 + \mu + 2\nu + \mu\nu)\frac{c}{\Delta}$

$\therefore \quad i_1 = \frac{E}{r^2\Delta}(2r^2 + 2mr + pr + np)$ $v_1 = \frac{mE}{r^2\Delta}(2r^2 + nr + pr + np)$

$i_2 = \frac{E}{r^2\Delta}(\quad mr + pr + np)$ $v_2 = \frac{nE}{r^2\Delta}(\quad mr + pr + np)$

$i_3 = \frac{E}{r^2\Delta}(2r^2 + mr + 2nr + mn)$ $v_3 = \frac{pE}{r^2\Delta}(2r^2 + mr + nr + mn)$

Given the values $m = 0.5$ $n = 0.2$ $p = 0.4$ $E = 110$

$i_1 = \frac{220r^2 + 22r + 44r + 8.8}{12r^3 + 8.7r^2 + 1.52r + 0.04}$ $v_1 = \frac{1100r^2 + 33r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$

$i_2 = \frac{55r + 44r + 22}{12r^3 + 8.7r^2 + 1.52r + 0.04}$ $v_2 = \frac{11r + 8.8r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$

$i_3 = \frac{220r^2 + 44r + 22r + 11}{12r^3 + 8.7r^2 + 1.52r + 0.04}$ $v_3 = \frac{88r^2 + 26.4r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$

$v_1 - v_2 = \frac{1100r^2 + 13.2r}{12r^3 + 8.7r^2 + 1.52r + 0.04} = 2$

$\therefore \quad 1100r^2 + 13.2r = 24r^3 + 17.4r^2 + 3.04r + 0.08$

$24r^3 - 982.6r^2 - 10.16r + 0.08 = 0$

$r^3 - 3.86r^2 - 0.4233r + 0.003334 = 0$

The solution of this is nearly $r = 0.0073$ $r^2 = 0.0000533$ $r^3 = 0.000000389$

$i_1 = \frac{0.011726 + 0.04818 + 8.8}{0.0004464 + 0.001096 + 0.04} = \frac{9.2935}{0.051560} = 180.25$ $v_1 = 90.125$

$i_2 = \frac{0.7227 + 22}{0.051560} = \frac{22.7227}{0.051560} = 440.80$ $v_2 = 88.160$

$i_3 = \frac{0.011726 + 0.04818 + 11}{0.051560} = \frac{11.4935}{0.051560} = 222.95$ $v_3 = 89.180$

If r corresponds to 1000 feet the res: per foot $= 0.0000073$ ω per foot $= 1500\,000$ cmils and there has to be 6000 feet $= 9,000,000$ cmils

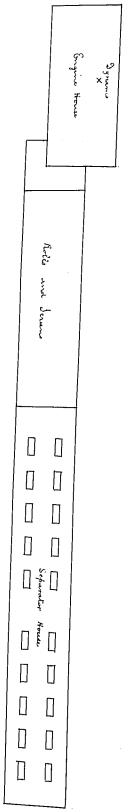
On the apparatus required for the Ore Separating Mills at Ogden N.J. (13)

The original series of 13 magnets (26 bobbins) was designed to operate at a p.d. of 110 volts see Book II p. 119-120, but 3 more magnets have since been added to the output of each series making 16 in all and raising the necessary pressure to $\frac{16}{13} \times 110 = \frac{1760}{13} = 135.5$ volts. To this estimate allowance has to be made say 5 volts for leads to generator, + 15 volts margin for any emergencies = 160 volts.

The distance from the dynamo to the center of the ~~factory in the~~ separator house is 275 feet. Allowing 1/2 volt in these leads = 2 each way, we have 35 ampères for each machine, and there will ultimately be 20 = 700 ampères carried 275 feet at 2 volts drop = $\frac{192500}{2} = \frac{96250}{96} = 1058$ *. These cables should therefore have 1,000,000 cmils. each. 600 feet of this cable should be ordered.

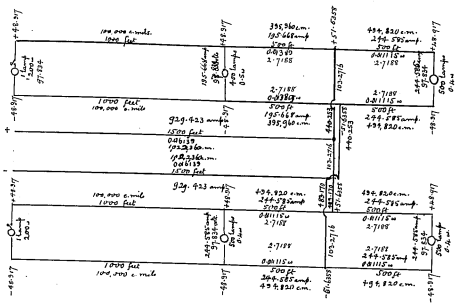
From the center of this room to any machine is under 100 feet. Allowing 1 volt drop in these leads or 0.8 each way we have $\frac{35 \times 100}{0.5} = 70 \times 77 = 77,000$ c.mils say #2 B.W.G. The mains one might be smaller. say 40,000 cmils #6 B.W.G.

A trial was made on the 23rd November, of the amount of power required to drive the experimental plant in the ore Milling Building. There were 16 magnets in series, taking 143 volts and 37 ampères = 5291 Watts = 7 H.P. and the motor running the belt pulleys at 62 revs. per min. took 120 volts + 40 ampères = 4800 Watts = 6.4 H.P. Total 10,091 Watts or 13.3 H.P.



Ground Plan of Refining Mills Ogden N.J. 1/32" to 1 foot or 1/8" to 1 foot

To determine the size and weight of conductors necessary to operate the hypothetical system shown on page 12 by the aid of feeders, keeping the same difference of pressure in the mains as exists in the last case.



The mains are of three sizes

4000 feet of	#100	= 400 million c.mils	
3000 - -	#494	1,484,460.000	
1000 - -	#396	395,960.000	
	8645 lbs. Total in main	2,280,420,000	
The feeders are for 30 volts, drop #1022	3000' 9.9 lbs	3.067.080.000	
	16,722 lbs. Total in system.	5.347.500.000 cmf	

@ 25¢ per lb - $4.030

Test of the Safety Conduit Tubes referred to in Book III. p. 105 + 118. 26th November 20.

These tubes have been immersed in the tanks on the roof under water since the 21st August 97 days in all. Their mechanical appearance is inferior, the outside paper being very weak. Three tubes were selected, and plugged with paraffined cork well coated over with paraffine wax. G.P. covered wires passed watertight through one cork. The tubes being filled with tap water. The resistances observed were

#1	10,000 ω	by Bridge	6 volts 1000/1000 Zic
#2	60,000 ω	- - - - - -	
#3	17,000 ω	- - - - - -	
1.2.+3	4,950 ω		

Each length 50 feet, 50000 ω for 30 feet = 150,000 ω per foot.
or 28·5 ω per mile

Loss. from 1656 volts 4 amperes or 4576 watts per mile
- - 4576 - 16 - - 7296 - - -

With one conductor in each tube making contact all round

Measurement of Inductances mh = Millihenry = Myriametre.

Telephone, Ordinary Bell type 168,969 A	1000/100	76.75Ω	0.93Ψ	= 0.07138		
including leads		.455		= 71.38mh		
Same with the diaphram removed		77.40Ω	0.61Ψ	= 47.22mh	66.1%	
Telephone, Special high resistance Bell type						
# 161,463 A including 0.455Ω leads	1000/1000	851.9Ω	0.203Ψ	= 173mh.		
Same with diaphram removed			0.145Ψ	= 123.5mh.	70.9%	
Telephone, Ordinary Bell type, 175,805A	1000/100	75.45Ω	1.05Ψ	= 79.22mh		
Same with diaphram removed		75.44	0.63Ψ	= 47.53mh.	60%	
Long distance telephone apparatus in the accountants office						
Telephone, Ordinary Bell type,	1000/100	74.70Ω	1.34Ψ	= 100.1mh		
all three wires like leads		0.343				
Same with diaphram removed		74.60	0.87Ψ	= 64.9	64.9%	
Bell in the apparatus, as set	10,000/1000	79.83	1.705Ψ	= 1.361 H		
Induction coil Primary	10,000/100		0.587Ω	= 0.600 = 3.522mh		
Secondary	1000/100	163.88	4.48	= 734.2mh		
Mutual inductance	1000/100	163.88Ω	4.89Ψ	= $\frac{801.4 - 734.2}{1.1}$ = 61.1mh		
reversed	-	-	4.09	= $\frac{734.2 - 670.2}{1.1}$ = 58.2mh		
				Mean = 59.65mh		
Inductor (call magneto) armature in the 2 annc apparatus	10000/1000	555.7Ω		1.32Ψ = 7.336 H		
		555.7Ω		0.485Ψ = 2.695 H		

Western Union Relay, Armature fan back (leads included) 0.3Ω						
140Ω type	10,000/1,000	139.78Ω	2.8Ψ	= 3.469 H.		
500Ω in ct.	10,000/1,000	638.6	0.8Ψ	= 3.193 H		
Armature hard down " "			1.5Ψ	= 3.579 H.		
W.U. Relay, Armature fan back	10,000/1000	650.3	0.468Ψ	= 3.026 H.	500Ω in ct	
140Ω type " hard down		850.3	0.360	= 3.06		
			5.6	= 3.50 H.	700Ω "	
W.U. Relay " fan back	10000/1000	838.5	0.380	= ~~3.44 H.~~	2.516 H.	700Ω in ct
140Ω type " average practical set			0.245	= ~~3.2 H.~~	4.82 H	
" hand down on magnets			4.9	= ~~44.1 H.~~	7.55 H	
W.U. Relay " fan back	10000/1000	209.8	0.091	= 191mh.	200Ω in ct + leads	
10Ω type " hand down	"	"	0.22	= 462 mh.	" " "	
" fan back	"	60.07	0.35	= 210 mh.	50Ω " "	
" hard down	"	"	0.82	= 493 mh.	" " "	
Pony Sounder - hard up	10000/100	6.625	0.431	= 285mh.	0Ω " "	
" " down	"	"	0.485	= 32.2 mh.	0Ω " "	
Pony Sounder - up	1000/10	5.596	0.42	= 23.5 mh.	5Ω " "	
" " down	"	"	0.83	= 46.46 mh.	5Ω " "	

Large vertical induction coil primary $\frac{10,000}{10}$ 0.3355Ω 1.78Ψ = 5.97 h.
leads 0.2617Ω res. 0.07138Ω

T.D. 20°C. secondary $\frac{10000}{100.000}$ 155.10Ω 2.825Ψ = 436 H
.9975 coils 16,1471 (= true ohms)

μ $\frac{.9975}{99,750}$, 155.10Ω = 15471 true ohms, + 2.71Ψ } = 16.1 H
reversed 2.94Ψ }

Large horizontal induction coil, secondary $\frac{104,000}{10,000}$ = 30,545Ω } mean 59 = 1520H
$\frac{99,750}{71,475}$ = 30,468Ω true }
balance at $\frac{104,000}{13,700}$ = 99,795Ω
= $\frac{99,795}{13,967}$ = 30,580Ω legal
= $\frac{99,795}{15,967}$ = 30,510Ω true 5Ψ = 1,978 H

primary 1000/10 = 0.2970Ω legal 4.42Ψ = 13.1 h
leads 0.1730Ω = 0.1430Ω μ

Mutual inductance 4.55Ψ. 163 H. secondary $\frac{104,000}{13,350}$ = $\frac{99,750}{13,100}$ = 40,780Ω = 30,600Ω legal
= 30,530Ω true = 1,978 H
2,036 H

19 + 9.93 = 28.93 − 20 − 8.93 × 0.03 − 0.252 9 Ψ = 39 = 15471
0.99747

Data relating to experimental induction Coil

A cylinder of insulating composition (6.5 long) and 2.7 in diameter was wound with # 73 turns of double cotton covered wire of 22 B.W.G. 0.025" (0.063) covered to 0.032" (0.081). The length of the helix is 60.75 so that there are 12.07 turns per cm. Over this solenoid fit loosely a shorter one 14.85 long) between flanges wound with turns of paper covered copper wire No. 22 B.W.G. 0.028" (0.071) covered to 0.031" (0.079). This second helix rests at the center of the first.

The resistance of the central helix is 3.70 ω. and its inductance is 7.53 kilometres = 753 microhenrys.

The area of the mean diam. of the helix (1.060" + 0.032) = 1.092" = 2.774 cm. = 6.04 sq. cm. so that the field h being 12.57 × 12.08 = 151.8. The flux per unit current = 917.2

The inductance per cm. should be 11,080 and the total inductance 673000 cms = 6.73 Kilometres. = 673 microhenrys.

The mutual inductance between the solenoid and the outer helix should be 917.2 per turn of the latter (in cms).

A Hughes bridge was arranged, and the inductance of a certain coil measured with an interrupter of low frequency. The inductance of this coil by bridge and accelerometer was 10000/10, 0.867, 0.0244 = 208 microhenrys. Balance was obtained for steady currents with telephone at 22.5 and 5 on the Porcelain scales. Total res: in bridge 100 + 5 + 17 = 122. Balance was nearly obtained for interrupted currents with 50 wires in circuit on the secondary helix ∴ μ = 45,860. Hence L = $\frac{45,860 \times 12.2}{22.5}$ = 248,700 cms = 249 microhenrys.

Data of Ballistic Galvanometer remounted 5th December

Bridge	Bridge Ratio	Temp. of Bridge	Temp. of Resistance for Ratio	Temp. of Resistance for Rest Coils	Observed Res:	Res: coils for temp. 19.3	Temp. of Galvo:	Sensitiveness	Inductance	Lamb.
	1000/1000	20°C	19°	28.4	5257 ω	5270 ω	21.2°C at Th:	0.380	2.008 H	0.4

The last measurement was made on the 3rd Oct: 1889 Book II p. 64.

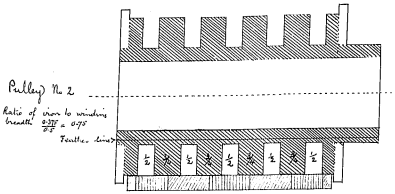
Inductance of the speaking mirror

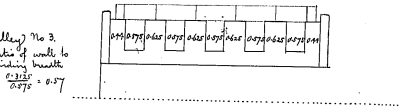
Ratio 1000/1000 Res: 2253.5 Sensitiveness 1.58

1002.5/1001.5 2248 3.57 H

5.4 × 0.03 = 0.252 × 52,57 = 13.

1000 . 1002.5

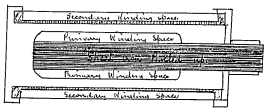


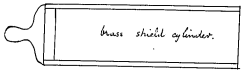


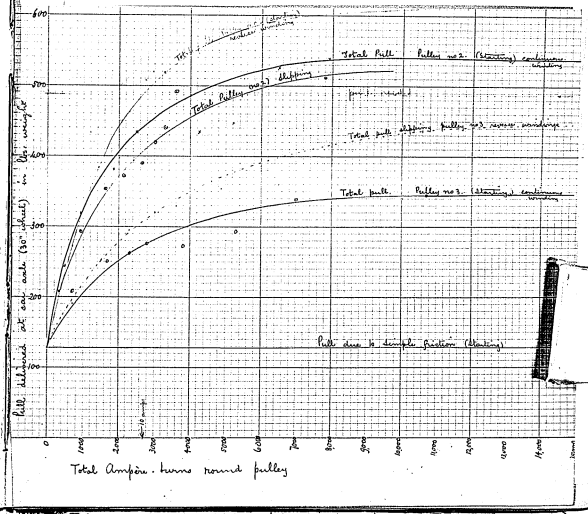
On the best windings for the experimental street Car Pulleys received from Schenectady

Pulley) no 2 received from Schenectady), and that with which the experiments detailed on p. 9 were made, was wound with 270 turns of # 17 B.W.G. copper wire 0.058".

Full sized cross section of coils and shielding cylinders.






Total Pull. Pulley no 2. (Stepping) continuous winding
Total Pulley no 2. stepping
Total pull stepping pulley no 2. reverse pondering
Total pull. Pulley no 2. (stepping) continuous winding
Pull done by simple friction (winding)
Pull delivered at any axle (180° apart) in lbs. weight
Total Ampère. turns round pulley

Data and description of a small medical induction coil to be operated by the Edison Lalande battery.

The primary winding consists of 6 layers? of 77 turns say 450 turns of # 23 B.W.G. 0.025" covered to 0.030".
The secondary winding consists of 6 layers? of 190 turns say 1140 turns of # 33 B.W.G. 0.007" covered to 0.013".

The inductances of the primary 1000/10 1.032 4.5[illegible] = 0.00496
" " " secondary 1000/100 785 1.27 = 4.9 mh.
" mutual " " for 1 sec. 1000/100 7850 1.92 = 0.0117h = 11.3 mh
" " " reversed " 78.62 0.95 = 0.0224h = 22.4 mh
Mean value 20.55 mh

No change appreciable in the mutual inductance when brass shield cylinder is inserted.
The resistance of the primary is 0.79 ω
" " secondary is 78.2 ω a ratio of nearly 100.

This induction coil is operated by one bichromate cell whose zinc plate, amalgamated, is a rod 11.5 long 0.9 in diam. and immersed to about 10 cm in depth exposing some 28 sq. cms. of surface, while the carbon plate is 10.0 × 3.0 × 0.7 immersed to about 8.0 cm exposing some 56 sq. cms. The distance between plate and rod is about 2 cms.

The E.M.F. of this cell is 2.0 volts, and its internal resistance 1.0 ω at its lowest. The current it gives through the closed primary circuit is 1.13 amp. and when operating the contact breaker 0.33 amp.

Two small Edison-Lalande cells of the telephony type were connected in series. Their e.m.f. = 1.49 volts, their combined int: res: 0.78 ω. The current on closed primary = 1.0 ampere.

Test of the power of one of the magnetic pulleys last used at Schenectady 29th Nov. 20.

Clock: Reading 2 x	Ampere	Reading of Ammeter	Accepted current	Amplitude from mean of the 6 throws of pulley	Weight	distance	Total Moment gm - cm.	Mean	Requirement full at one end cm.	Mean
0.000	0	0.0	0	0	40 lbs.	7.8"	160		128	
1.128	1.31	1.5	1.3	351	+ 24	50"	280 (100)		208	80
3.320	4.00	4.5	4.0	1080	+ 48	60"	480 240		320	192
6.655	6.72	8.0	6.7	1810	+ 48	79".	476 316		381	253
-	-	10.0	9.4	2540	+ 48	96".	544 384		435	307
1.17	12.0	12.0	12.0	3240	+ 67	87.5"	649 489		519	391
-	-	16.0	15.7	4240	+ 85	54"	543 383		435	307
1.88	19.3	20.0	19.3	5210	+ 85	56.5"	560 480		448	320
2.35	24.1	27	24.1	6510	+ 85	70.25	658 498		527	399
2.60	26.7	30	26.7	7210	+ 85	-	- -		-	-
2.85	29.2	35	29.2	7885	+ 85	72.5	674 574		539	411
5.2	53.4	44	53.4	14420	+ 85	63.5 ?	640 450		488	360

In the case presented $b = 80$ $C = 50$ $t = 40000$

$n = \frac{500}{60} = 8.33$

$R = 28.9$ $r = 23.4$ $R - r = 5.5$

Assume the constants $k = 1.0 \times 10^{-8}$

$f = 500$

$a = 0.9$ $a y = 0.8$ $a^2 y^2 = 0.65$

$g = 0.9$

$\rho = 1.8 \times 10^{-6}$

$p = 4$

$l = 1$ (trial)

$h = 0.98$

$$b = \frac{40000 \times \sqrt[3]{\frac{80 \times 0.02 \times 0.65 \times 23.4 \times 23 + \times 16 \times 1}{2 \times 50 \times 0.98 \times 1.8 \times 10^{-6} (10+6)}}}{2 \times 500 \times 9.86 \times 10^{8} \times 44 \times 0.98 \times 8.33 \times 0.65 \times 23.4 \times 23 + \times 5.5 \times 10^{-8}}$$

$$= \frac{40000 \times \sqrt[3]{\frac{9112}{2823 \times 10^{-6}}}}{630\,70}$$

$$= \frac{400000 \sqrt[3]{3.228}}{63,070} = \frac{400000 \times 1.478}{63,070} = \frac{591,120.00}{63,070}$$

$$= 9.37$$

b is thereon as 16·8. Retaining Rise and reducing $R - r$ in the ratio $\frac{9.37}{16.8} = \frac{5.5 \times 9.37}{16.8} = 3.068$ say. and $r = 25.8$

$\phi = 2 \times 10,000 \times 3.1 \times 16.8 = 1,042,000$ useful lines

$\phi = 920,000$ useful lines.

$\omega = \frac{8.0 \times 10^{8}}{10^{8} \times 5.33 \times 0.9} = \frac{8.0 \times 10^{3}}{5.8 + 0} = 0.940$ say 0.960.

$= 240$ wires per quadrant.

The circumference of $25.8 = 10'' = 62.8'' \times 0.9$, $\frac{56.52}{0.960} = 0.058$

When uncovered this wire will be $0.050''$ say. $= 2500$ c.mil, and 12.5 amp 200 c.mil per amp.

Calculations for a proposed form of Marine Quadripolar Dynamo on a design of Mr Phelps Eng. Dept. N.Y.

(19)

Consider the general equations of a multipolar gramme ring dynamo, carried to the first approximation

Let r = the int: radius of the armature core (cms)

R = " ext: " " " " (cms)

b = " breadth " " " (cms)

d = " diameter — " " copper wire on armature. (cms)

D = " " " " " " covered. (cms)

ω = " number of the wires counted all round.

ϕ = " polar flux (Gaslines)

p = " number of poles

l = " number of layers of wire on the armature.

γ = " permissible density of current in the wire (amps per sq cm.)

T = " energy developed electrically (watts)

t = " electrical effic energy delivered (watts)

b = " density of induction in the core-space (C.G.S)

a = " constant of reduction for armature winding spaces

g = " " " " wire covering or ($\frac{d}{D}$)

c = " current generated in the wire at full load say

C = " total " " " armature " " amps

E = " volts generated

e = " " at machine terminals on full load.

k = " ratio of e to E

n = " number of revs. of the armature per second.

Then

$$E = \phi n \omega \times 10^{-8} \quad (1)$$

$$e = k \phi n \omega \times 10^{-8} \quad (2)$$

$$\phi = 2 \mathfrak{B} (R - r) b \quad (3)$$

$$t = \frac{t}{e} e C = C k \phi n \omega \times 10^{-8} = p c \rho \phi n \omega \times 10^{-8} \quad (4)$$

$$D = \frac{a 2\pi r l}{\omega} \quad (5)$$

$$d = \frac{a g l 2\pi r}{\omega} \quad (6)$$

$$c = \gamma \frac{\pi}{4} \frac{a^2 g^2 4\pi^2 r^2 l^2}{\omega^2} \quad (7)$$

$$\therefore t = \gamma \frac{\pi}{4} \cdot \frac{a^2 g^2 4\pi^2 r^2 l^2}{\omega^2} \cdot p k \phi n \omega \times 10^{-8} \quad (8)$$

$$= \gamma \frac{\pi}{4} \cdot \frac{a^2 g^2 4\pi^2 r^2 l^2}{\omega^2} \cdot p k . 2 \mathfrak{B} (R - r) b n \omega \times 10^{-8} \quad (9)$$

$$t = 2 \gamma \pi^2 \mathfrak{B} b p k n a^2 g^2 r^2 l^2 \times 10^{-8} (R - r) \quad (10)$$

$$Q = \frac{\omega \frac{d}{2} (b + R - r) \pi}{\frac{\pi}{4} (d^2)} = \frac{\omega^2 g \mathfrak{B} (b + R - r) \rho}{\pi a^2 g^2 4\pi^2 r^2 l^2} \quad (11)$$

where a is the resistance of the other wire in series q res. between brushes and ρ resistivity not in ohms, of the wire

$$q = \frac{2 \omega \mathfrak{B} b (b + R - r + ld)}{\mathfrak{B} a^2 g^2 \pi^2 r^2 p^2 l^2} \quad (12)$$

$$C q = e \left(\frac{1 - h}{h} \right) \quad (13)$$

$$\therefore \omega^3 = \frac{e (1 - h) a^2 g^2 \pi^2 r^2 p^2 \mathfrak{B}^2}{2 C h \mathfrak{B} \rho (b + R - r + ld)} \quad (14)$$

$$\therefore t = \frac{2 \gamma \pi^2 \mathfrak{B} b p k n a^2 g^2 r^2 l^2 \times 10^{-8} (R - r)}{\sqrt[3]{\frac{e (1 - h) a^2 g^2 \mathfrak{B}^2 \pi^2 r^2 p^2 \mathfrak{B}^2}{2 C h \mathfrak{B} \rho (b + R - r + ld)}}} \quad (15)$$

$$\text{or} \quad b = \frac{t \sqrt[3]{\frac{e (1 - h) a^2 g^2 r^2 p^2 \mathfrak{B}^2}{2 C h \rho (b + R - r + ld)}}}{2 \gamma \pi^2 \mathfrak{B} p k n (a^2 g^2 r^2 l^2) (R - r) \times 10^{-8}} \quad (16)$$

And this is the evaluation of b to a first approximation from R, r, e, C and known constants.

Calculations for a 14 Kilowatt dynamo designed by the Engineering Department. Continued. See also p 83

$(R-r)$ is 5·5 and t is 16·8, the cross section is 92·4 sq. cms and allowing 9000 per sq. cm gives 831,600 lines usefully conducted or 1,663,200 lines for ϕ. $n.$ = 5·83 ϕn = 13856 x 10^3 $\therefore w = \frac{800}{1376} =$ 577·3 ~~say 600~~. Having ample space say 800. The int: diam: being 9·2 x 2" = 18·4" the int: circumference is 57·8" and the breadth per wire = 0·072". Allowing 0·012" this becomes 0·060", nearest size 0·058" # 17 B.W.G. C. mils 3364 = 260 c.m. per amp.

The value of r may be taken as 1·6 so that ϕ in the cores will be 1·6 x 1216·000 = 1,945,000 and in wrought iron with $\mathfrak{L}$ = 12,000 = 162 sq. cms. = ~~#24~~ 81 sq. cms. in each core = 10·2 cms = 4" in diameter; allow ~~#8~~ 4·0.

The polar area is 14 x 16 sq. cms = 224 sq. cms. and the entrefer will be 0·10" + 0·070" + 0·125" = 0·205" = 0·5 cm ~~10~~ that the total air reluctance is $\frac{1·0}{224}$ = 0·0045 lines. The reluctance of the rest of the circuit will be 0·0045 - Total 0·009 The m.m.f. needed for 972,000 lines = 10,000 = 8000 amp. turns = 5330 turns on each core, each offering 27·5 ω hot. The mean turn being 1·25 feet these will be 6660 feet per core = 5328 ft per ohm = # 15 B.W.G. 0·072" @ 7·88 lbs = 99 lbs. in each

Allowing 2 amperes per core, the turns are 4000 offering 19·2 ω hot = 5000 feet or 500 ft per ω = # 15 B.W.G. 0·072 @ 7·88 = 79 lbs.

For 694,000 lines 6000 mmfs are needed - # 800 J.T. = 24.000 turns offering 10 ω = 3000 feet = 300 ft per ω = # 17 B.W.G. 3000' = 30 lbs. of wire.

Requirements 30 lbs of # 17 B.W.G. 0·058" on each core or 120 lbs. in all
1 layer of # 17 B.W.G. on the armature in 800 turns = 200 per sector, and 200 commutator blocks.

Experiment on the effect of an aqueous solution of Tetra-ethyl ammonium iodide injected into the arterial system of a rabbit. 1st December 90

It was found that 300 divisions, supposed to be minim divs: of the hypodermic injector scale represent 28·8 c.c. so that each div: represents 0·073 c.c.

After cleansing the injector first with carbolic acid and then with boiling water, injected 0·25 c.c. of the 1% solution in water of tetraethylammonium into the vein on the right ear of the small white rabbit at 16 o'clock.

On the following morning injected 0·5 c.c. of the same solution into the two ears of the same rabbit at 9 o'clock.

On the 3rd Dec. 0·5 c.c. of 1% solution was injected into the left ear of the larger rabbit.

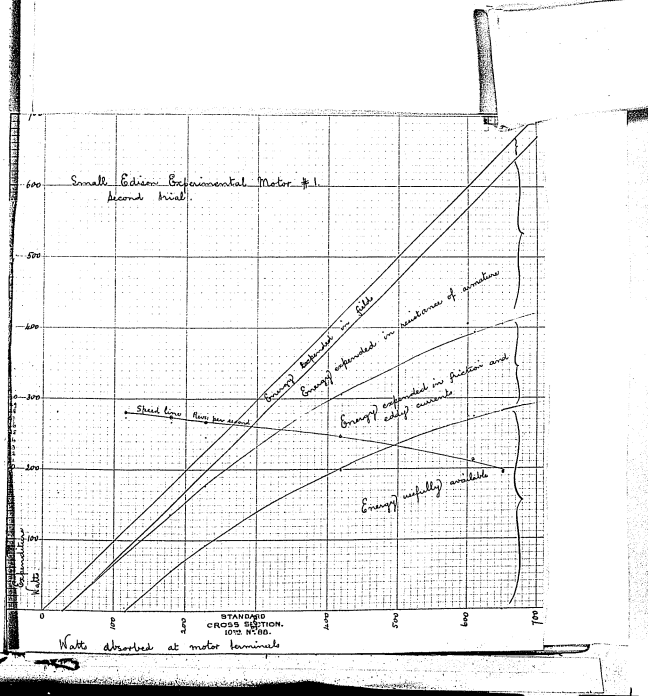
On the 4th Dec. 0·75 c.c. of 1·7% solution was injected into the right ear of the larger rabbit.

On the 6th Dec: 0·75 c.c. of 3·0% solution was injected into the right side of the larger rabbit.

On the 8th Dec: 0·75 c.c. of 3·0% solution was injected into the right side of the smaller rabbit.

On the 10th Dec: 1·0 c.c. of 3·0% solution in flour pills was administered to the larger rabbit by the mouth

No. of Obs.	P.D. on motor	Brush	Current in motor	Energy in motor	Energy in field	Energy in armt.	Calculated new Ers in armt.	Difference	Revs. per min.	Revs. per sec.	Interval in secs.	Ratio
1	122·5	0·046	0·236	28·9	28·9	0	0	0	~~1085~~	~~25·42~~		-
2	"	0·185	0·949	116·2	28·9	87·3	4·2	83·1	1685	28·60	5·92	116·6
3	"	0·285	1·462	179·1	~~150·2~~ "	150·2	12·48	137·7	1646	27·42	10·18	112·3
4	"	0·362	1·857	227·5	"	198·6	21·80	176·8	1625	26·75	13·45	109·0
5	"	0·665	3·411	417·8	"	388·9	83·66	305·2	1478	24·63	26·35	96·6
6	"	0·970	4·976	609·5	"	580·6	186·5	394·1	1271	21·18	39·35	83·1
7	"	1·035	5·309	650·3	"	621·4	213·6	407·8	1177	19·62	42·10	80·4
8	"	1·300	6·668	816·8	"	787·9	392·4	395·5	910	15·16	61·10	61·4



Test of small Edison motor Second Trial 2nd Dec: 90.

The machine has been been fitted with a new field magnet, and the same field wire has been transferred from the old field. The shaft has been increased to 0.5", and the armature connections have been made to the commutator through 0.01" platinoid wire.

Watts per lamp for test	Scale	Reading	Torque	Energy in watts	Energy lost in armature	Energy lost in field	Total	Electrical Efficiency	Mechanical Efficiency	Remarks
0	0	0	0	·0						Field only
4·150	0	0	0	0	83·1	4·2	87·3	0·715	·0	Running light
4·095	{·50 @ 8 200 @ 25}		3400	57·5	80·2	12·5	150·2	0·769	0·321	Driving dynamo light
4·075	{50 @ 17 200 @ 24}		5650	93·2	83·6	21·8	198·6	0·777	0·41	- dynamo now separately excited field
3·902	{50 @ 12·3 100 @ 25 1000 @ 10}		13,115	199·2	106·0	83·7	388·9	0·730	0·477	Load 107·5 v 0·9 a
3·924	{50 @ 18·1 1000 @ 20}		28905	273·0	121·1	186·5	580·6	0·646	0·448	- " 2 amp
4·100	{50 @ 16·2 500 @ 5 1000 @ 20}		23315	282·0	125·8	213·6	621·4	0·656	0·434	87 v 2·5 amp
4·050	{50 @ 13 200 @ 5 500 @ 15 1000 @ 20}		29,150	272·4	123·1	392·4	787·9	0·502	0·334	3·6 amp

The temp: on the armature was to 200°F after the run of about 20 minutes. The res: of the armature very warm is 9·55 v, and fairly warm 8·32. The field warm 6·30.

Weight of machine with base 37½ lbs

Convention. The quantity discharged through any electromagnetic circuit traversed by a steady current, after the removal of that current by a short circuit, is called the charge of that circuit.

Charging

The natural logarithm of the ratio of the $\left\{\begin{matrix}\text{charge}\\\text{initial current}\end{matrix}\right\}$ to the $\left\{\begin{matrix}\text{deficit of charge}\\\text{charging current}\end{matrix}\right\}$ at any instant is the quotient of the charging time during which charge has been in progress by the time constant of the circuit.

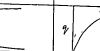
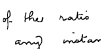
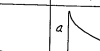
Discharging

The natural logarithm of the ratio of the $\left\{\begin{matrix}\text{charge}\\\text{initial current}\end{matrix}\right\}$ to the $\left\{\begin{matrix}\text{residual charge}\\\text{discharging current}\end{matrix}\right\}$ at any instant is the quotient of the time during which discharge has been in progress by the time constant of the circuit.

The charge is the quantity which would traverse the circuit if the initial charging current were active for a time equal to the time constant of the circuit.

The energy of the charge is equal to half the energy that would be developed by the initial charging current if sustained uniformly, against the resistance of the circuit, during a time equal to the time constant of the circuit.

On some interesting relationships between closed electromagnetic circuits and condensers.

	Inductances. Charges	Inductances. Currents	Permittances. Charges	Permittances. Currents
(1) Charging				
	$dq = C(1-\varepsilon^{-\frac{t}{\tau}})\,dt$ $= C\,dt - C\varepsilon^{-\frac{t}{\tau}}dt$ $q = Ct + C\tau(\varepsilon^{-\frac{t}{\tau}}-1)$ $= Ct + Q(\varepsilon^{-\frac{t}{\tau}}-1)$ $Q-q = Q(\varepsilon^{-\frac{t}{\tau}}-1)$ $Cc-q = Q(1-\varepsilon^{-\frac{t}{\tau}})$ Charge $= Q(1-\varepsilon^{-\frac{t}{\tau}})$ $\frac{\text{Charge}}{Q} = 1-\varepsilon^{-\frac{t}{\tau}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{\tau}}$ $\log_\varepsilon \frac{Q}{\Delta q} = \frac{t}{\tau}$	$c = C(1-\varepsilon^{-\frac{t}{\tau}})$ $\frac{c}{C} = 1-\varepsilon^{-\frac{t}{\tau}}$ $\frac{c-C}{C} = -\varepsilon^{-\frac{t}{\tau}}$ $\frac{C-c}{C} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{\Delta c}{C} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{c}{\Delta c} = \varepsilon^{\frac{t}{\tau}}$ $\log_\varepsilon \frac{C}{\Delta c} = \frac{t}{\tau}$	$\frac{dq}{dt} = \frac{c-q}{\tau}$ and $v = \frac{q}{C}$ $\frac{dq}{dt} = C - \frac{q}{\tau} = C - \frac{q}{RC}$ $q = \varepsilon^{-\int\frac{dt}{\tau}}(\int\varepsilon^{\int\frac{dt}{\tau}}C\,dt + K)$ $= \varepsilon^{-\frac{t}{\tau}}(C\int\varepsilon^{\frac{t}{\tau}}dt + K)$ $= \varepsilon^{-\frac{t}{\tau}}C(\varepsilon^{\frac{t}{\tau}}-1)+K\varepsilon^{-\frac{t}{\tau}}$ $= Q(1-\varepsilon^{-\frac{t}{\tau}}) + 0$ $\frac{q}{Q} = 1-\varepsilon^{-\frac{t}{\tau}}$ $\frac{q-Q}{Q} = -\varepsilon^{-\frac{t}{\tau}}$ $\frac{Q-q}{Q} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{Q}{\Delta q} = \varepsilon^{\frac{t}{\tau}}$ $\log_\varepsilon \frac{Q}{\Delta q} = \frac{t}{\tau}$	$\because q = Q(1-\varepsilon^{-\frac{t}{\tau}})$ $c = C - \frac{Q}{\tau}(1-\varepsilon^{-\frac{t}{\tau}})$ $= C - Q(1-\varepsilon^{-\frac{t}{\tau}})$ $= C - C\varepsilon^{-\frac{t}{\tau}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{C-c}{C} = \varepsilon^{\frac{t}{\tau}}$ $\log_\varepsilon \frac{C}{C} = \frac{t}{\tau}$
(2) Discharging				
	$c = Q\varepsilon^{-\frac{t}{\tau}}$ $dq = C\varepsilon^{-\frac{t}{\tau}}dt$ $q = -C\tau(\varepsilon^{-\frac{t}{\tau}}-1)$ $\frac{q}{Q} = 1-\varepsilon^{-\frac{t}{\tau}}$ $\frac{q-Q}{Q} = -\varepsilon^{-\frac{t}{\tau}}$ $\frac{Q-q}{Q} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{\tau}}$ $\log_\varepsilon \frac{Q}{\Delta q} = \frac{t}{\tau}$	$c = C\varepsilon^{-\frac{t}{\tau}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{C}{c} = \varepsilon^{\frac{t}{\tau}}$ $\log_\varepsilon \frac{C}{c} = \frac{t}{\tau}$	$\frac{-dq}{dt} = \frac{q}{\tau} + v = \frac{q}{\tau}$ $-dq = \frac{q}{\tau}dt = \frac{q}{RC}dt$ $\frac{-dq}{q} = \frac{dt}{\tau}$ $-\log_\varepsilon q = \frac{t}{\tau} + K$ when $t = 0$ $q = Q$ $-\log_\varepsilon Q = K$ $-\log_\varepsilon q = \frac{t}{\tau} + \log_\varepsilon Q$ $\log_\varepsilon \frac{Q}{q} = \frac{t}{\tau}$	$\because v = \frac{q}{\tau}$ and $v = \frac{q}{RC}$ $c = \frac{q}{C}$ $q = Q\varepsilon^{-\frac{t}{\tau}}$ $c = \frac{Q}{C}\varepsilon^{-\frac{t}{\tau}}$ $= C\varepsilon^{-\frac{t}{\tau}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{\tau}}$ $\frac{C}{c} = \varepsilon^{\frac{t}{\tau}}$ $\log_\varepsilon \frac{C}{c} = \frac{t}{\tau}$
	$\int dQ = C\int\varepsilon^{-\frac{t}{\tau}}dt$ $Q = C\tau$		$C = \frac{q}{v}$; $C\tau = \frac{q}{v}\times\int\tau$; $= e\int_1 = Q$ $\therefore Q = C\tau$	
	$dT = e\,dt$ $= \tau C^2\varepsilon^{-\frac{t}{\tau}}dt$ $T = \tau C^2\int_0^\infty\varepsilon^{-\frac{t}{\tau}}dt$ $= \tau C^2\frac{\tau}{2}$		$T = \int v\,dq = \int\frac{q}{\tau}dq = \frac{1}{\tau}\int_0^Q q\,dq$ $= \frac{1}{\tau}\frac{Q^2}{2} = \frac{1}{\tau}\times\frac{C^2\tau^2}{2} = \frac{1}{\tau}\frac{C^2\tau^2}{2}$ $= C^2\tau\times\frac{\tau}{2}$	

Test of the power of magnetic pulley no 3 3rd Dec: 1890.

Conditions of test the same as that already recorded on page 18.

No of Obs.	Ammetre	Obach	Current amperes	accepted current	Ampère turns	Load lbs.	distance inches	Moment ft lbs.	Added	Total	Pull at axle
1	2	0·35	1·795	1·8	720	24·5	80	100	160	260	208
2	4	0·820	4·103	4·1	16140	"	76	152		312	250
3	6	1·14	5·848	5·85	2340	"	84	168		328	262
4	8	1·55	7·950	7·95	2780	"	93	186		346	277
5	10	1·89	9·694	9·69	3876	48	45	180		340	272
6	15	2·58	13·23	13·23	52 92	"	51·5	206		366	293
7	19	3·40	17·44	17·44	6976	"	61	244		424	339
8	28	5·20	26·68	26·7	10 680	"	62	268		428	343
9	34	6·40	32·8	32·8	13 120	"	63	272		432	346

The curve is added to the sheet on p. 18.

Test of Large 8" pulley 4th Dec: 1890 Weighing method.

No of Obs.	Ammetre	Obach Ammetre	Obach Permanent amperes	accepted current	Ampère turns	Load	Dist: Feet	Moment ft-lbs	Pull at axle	
1	2	0·335	1·72	1·72		41·5	8	332	266	
2	4	0·82	4·10	4·10		101·5	"	812	650	
3	6	1·21	6·21	6·21		121·5		972	778	
4	7	1·39	7·13	7·13		126·5		1012	810	
5	9	1·625	8·33	8·33		140		1120	896	
6	13	2·55	13·08	13·08		151·5		1212	970	

Test of Pulley no 3. after rewinding grooves in alternate directions.

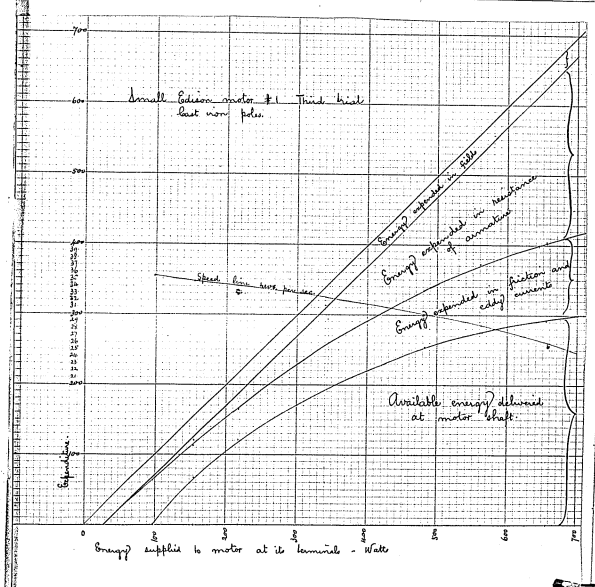
No of Obs.	Ammetre	Obach	Current amperes	Ampère turns	Load	distance inches	Moment ft-lbs.	Added	Total	Corresponding Pull at axle
1	2		1·8	720	80	96	80	friction		64
2	4	0·745	3·82	1528	19	"	152			122
3	6	1·10	5·64	2256	26	"	208			166
4	8	1·55	7·95	3180	30	"	240			192
5	10	1·75	8·98	3592	31·5	"	252			202
6	15	2·40	12·3	4920	35	"	280			224
7	28	5·15	26·42	10560	48	"	384			307
8	2	2×0·175	1·8	720	24	61	122	56	178	142
9	4	0·35	3·59	1436	48	66	264		320	256
10	6	0·57	5·85	2340	48	86	344		430	334
11	8	0·72	7·38	2952	67	74·5	416		490·5	392
12	10	1·02	10·46	4184	61	73	371		437	350
13	27	2·35	24·1	9640	109	70	566		622	497

No. of Obs.	P.D. on motor	Rheostat	Current in motor	Energy in motor	Energy in field	Energy in armt.	Calculated res. loss in armt.	Difference	Revs. per minute	Revs. per second	duty in armt.	p.d. in armt.
1	122·0	0·047	0·24	29·3	29·3	-						
2	"	0·155	0·795	97·0		67·7	2·55	65·2	2926	35·4	3146	117·4
3	"	0·250	1·282	156·1		126·8	9·012	117·8	2056	34·75	8·67	113·3
4	"	0·350	1·795	219.		189·7	20·06	169·6	1980	33·0	12·9	109. 1
5	"	0·770	3·950	482.		452·7	114·6	338·1	1814	30·3	30·9	91·1
6	"	0·990	4·617	563.		533·7	159·3	374·4	1712	28·5	36·44	85·6
7	"	1·05	5·385	657.		627·3	220·2	407·1	1525	25·4	42·8	79·2
8	"	1·46	7·488	913·5		884·2	472·5	411·7	1043	17·4	65·2	56·8

Efficiency test of 1 parall motor with cast iron field poles. Continued from page 21. Same model. December 3rd 1890.

24

R.P.M. per min: from obs.:	Scale Reading	Torque in gm.	Energy delivered	Energy lost in friction	Energy lost in res. of armt.	Total	Electrical Efficiency.	Mechanical Efficiency.	Conditions
-	-		0						
3·316	{200 @ 45 / 200 @ 25}			65·2	2·5	67·7	0.672	-	Field only
3·260	{50 @ 45 / 200 @ 25}	3,175	68	49·8	9·0	126·8	0.755	0.436	Running light
3·306	{50 @ 30·0 / 1000 @ 20 / 1000 @ 10}	5950	121	48·6	20·1	189·7	0.774	0.550	Driving - . Res. in E. field
3·007	{50 @ 15 / 200 @ 12 / 1000 @ 10}	13,550	253	85·1	114·6	452·7	0.701	0.525	load of 1 amp
2·804	{50 @ 23 / 200 @ 20 / 1000 @ 10}	15,600	275	99·4	159·3	533·7	0.668	0.488	1·5 .
3·120	{50 @ 12 / 1000 @ 10 / 1000 @ 3a}	11,600	204	116·1	220·2	627·3	0.620	0.443	1·9 .
3·265	{50 @ 11·5 / 1000 @ 10 / 1000 @ 3a}	24,075	280	131·7	472·5	884·2	0.451	0.287	3·1 .


Small Edison motor #1 Third brush Cast iron poles.
Energy expended in friction
Energy expended in resistance of armature
Energy expended in friction and eddy currents
Available energy delivered at motor shaft.
Speed line over pulley
Energy supplied to motor at its terminals - Watts
Energy delivered

On the equations of gramme ring motors with any number of poles, with the formula for determining the armature breadths.

Let r = the int: radius of core (cms)
R = " ext: " " "
b = " breadth of core "
n = " no: of turns made by armature per second
p = " no: of poles
w = " no: of wires counted all round the armature
D = " diameter of the covered wire (cms)
d = " " " " copper wire (")
a = " armature surface coefficient of reduction for winding
g = " covering coefficient $\frac{d}{D}$
l = " length of one turn round the armature.
l = " number of layers
γ = " current density in the wire (amps. per sq cms)
c = " current in the wire (amps.)
C = " " " brushes or armature cct. (amps)
Q = " resistance of the whole ring
q = " resistance of the armature
λ = " coeff: of increase of armature res: for platinoid.
$\mathfrak{B}$ = " mean coeff inductive density in the cross section of the core (gauss)
ϕ = " polar flux C.G.S.
e = " e.m.f. generated by the armature (volts)
E = " " " guaranteed at " " terminals (volts)
h = " armature efficiency or e/E
t = " mechanical energy (ergs) delivered by the shaft (Watts)
T = " " " absorbed by armature
m = " efficiency of armature $= \frac{t}{T}$

$T = EC = \frac{e}{h} C$

$t = mEC = \frac{meC}{h}$

$e = \phi n w \times 10^{-8}$

$\phi = 2\mathfrak{B}(R-r)b$

$e = 2\mathfrak{B}(R-r)bnw \times 10^{-8}$

$D = \frac{2\pi r a l}{w}$

$d = \frac{2\pi r a g l}{w}$

$c = \gamma \frac{\pi}{4} \cdot \frac{4\pi^2 r^2 a^2 g^2 l^2}{w^2} = \frac{\gamma \pi^3 a^2 g^2 l^2 r^2}{w^2}$

$C = \frac{b \mathfrak{B} \pi^3 a^2 g^2 l^2 r^2}{w^2}$

$t = \frac{n \phi n w 10^{-8} \cdot b \mathfrak{B} \pi^3 a^2 g^2 l^2 r^2}{h w^2}$

$t = \frac{2\mathfrak{B}(R-r) b m n b \mathfrak{B} \pi^3 a^2 g^2 l^2 r^2 \cdot 10^{-8}}{hw}$

$a = \frac{w \circ \rho}{\frac{\pi}{4} d^2} = \frac{4 w^3 \circ \rho}{4\pi^2 a^2 g^2 l^2 r^2} = \frac{w^3 \circ \rho}{\pi^2 a^2 g^2 l^2 r^2}$

$q = \frac{w^3 \circ \rho \lambda}{b^2 \mathfrak{B}^2 \pi^3 a^2 g^2 l^2 r^2}$

$C q = E(1-h)$

$q = \frac{E}{C}(1-h)$

$w^3 = \frac{E}{C}(1-h) \frac{b^2 \mathfrak{B}^2 \pi^3 a^2 g^2 l^2 r^2}{\circ \rho \lambda}$

$w = \pi \sqrt[3]{\frac{E(1-h) b^2 a^2 g^2 l^2 r^2}{C \circ \rho \lambda}}$

$b = \frac{th \sqrt[3]{\frac{E(1-h) b^2 a^2 g^2 l^2 r^2}{C \circ \rho \lambda}}}{2\mathfrak{B}(R-r) m n b \mathfrak{B} \pi^3 a^2 g^2 l^2 r^2 \cdot 10^{-8}}$

$= \frac{t h \sqrt[3]{\frac{E(1-h) b^2 a^2 g^2 r^2}{C \circ \rho \lambda}} 10^8}{b^{\frac{2}{3}} 2\mathfrak{B}(R-r) m n b \mathfrak{B} \pi^3 a^2 g^2 l^2 r^2}$

$= h t \frac{\sqrt[3]{\frac{E(1-h) b^2 a^2 r^2}{C \circ \rho \lambda}} \times 10^{\frac{8}{3}}}{2\mathfrak{B}^{\frac{5}{3}} \pi^2 g^2 l^2 \sqrt[3]{b} \mathfrak{B}(R-r) m n \rho a^2 r^2}$

$$b = \frac{100 \times 0.9 \sqrt[3]{\frac{110 \times 0.1 \times 0.25 \times 8.944 \times 4 \times 26.0}{1.4 \times 9 \times 1.8 \times 1.1}} \times 10^{+60}}{g^{\frac{2}{3}} l^{\frac{1}{3}} \times 2 \times 0.25 \times 8.944 \times 4 \times 26.0 \times 10,000 \times 500 \times 0.65 \times 30 \times 2 \times 9.86 \times 2.5}$$

$$= \frac{0.9 \sqrt[3]{\frac{11 \times 26}{11.2 \times 1.93}} \times 10^{8}}{g^{\frac{2}{3}} l^{\frac{1}{3}} \times 65 \times 0.65 \times 850 \times 9.86}$$

$$= \frac{2146}{g^{\frac{2}{3}} l^{\frac{1}{3}}}$$

If $g = 0.85$ $g^{\frac{2}{3}} = 0.81$ $b = 2646/l^{\frac{1}{3}}$

If $l = 10$ $l^{\frac{1}{3}} = 21.6$
$l = 2$ $l^{\frac{1}{3}} = 2.5$
$l = 3$ $l^{\frac{1}{3}} = 4.3$
$l = 4$ $l^{\frac{1}{3}} = 6.35$

Electromagnetic design for a 100 = Watt Edison motor. (26)

Retaining the same patterns as the ½ HP motor and with the same diameter of armature the formulas for breadth becomes

$$b = \frac{th \sqrt[3]{E(1-h)10^8 \rho^2 \pi^2}}{\cos x \; 2\pi^{\frac{2}{3}} a^2 \rho b^2 \cdot 8 f \sigma n \mu \sigma^2 (R-r)}$$

$t = 100$ $h = 0.9$ $E = 110$ $a = 0.5$ $y = 0.85$ $t = 5.1$ $R = 7.6$ $\rho = 2$ $\mathfrak{L} = 14,000$
$a^2 = 0.25$ $g^{\frac{2}{3}} = 0.7225$
$\rho = 1.8 \times 10^{-6}$ $C = 1.4$ $n = 30$ $f = 500$ $\sigma = 8$ $\lambda = 1.1$ $m = 0.65$

Hence, $b = \frac{16.4}{g^{\frac{2}{3}} l^{\frac{1}{3}}}$. Taking a trial value of g as 0.85

$b = 20.24/l^{\frac{1}{3}}$

For $l = 10$ $b = 0.95$

With the same values $w = 960$ say 966

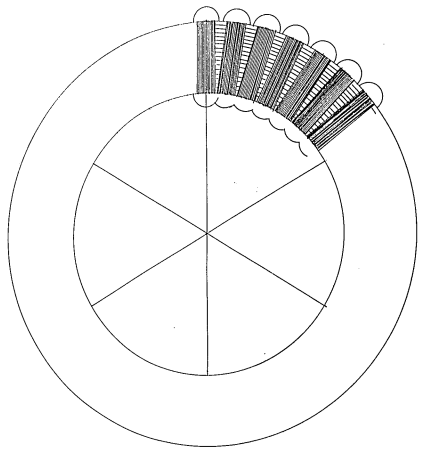
The induction-density in the core of the ½ HP model is 14,450. depth being 2.5, gives a flux of 72,250 lines per cm. of width of core. Taking 0.8 cm ($\frac{1}{3}$rd") we have a useful flux of 57,800 lines. With $n = 30$ $qn = 1734 \times 10^4$ and to generate 110 volts, the wire have to be 6345. The winding breadth in the grooves, = 0.20" and 12 turns in this space = 0.0166" = 0.014" copper = # 28 B.W.G. The number of layers will be 14 = 168 wires in each groove = 42 feet = $55 \times 42 \times 10^{-12}$ = 2.3 ω per groove. The total res. = 96.6 ω, and the res. between brushes 24.2 ω. At full load of 1.5 amps, the fall of potential will be 36 volts or 33%, This is perhaps excessive. # 27 B.W.G. the next wire = 0.016" diam = 0.018" covered and 12 = 0.216 say 0.22" broad, while 14 = 0.252" high. 142 feet = 1.8 ω hot per groove = 19.9 ω in the whole armature, with platinoid say 19.5 ω hot. The speed being 1800 per min: at no load with falls to 1300 on full load or 27%.

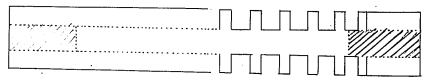
The flux to be supplied is 57,800 with leakage say 100,000. The density in the core is say 12,500 = 8 sq. cms. the diam of which = 3.89 sq. cms: = 1¼". The reluctance of the circuit is 0.01 and to drive 60000 lines through it requires 6000 AM.T. = 4800 amp. turns. With 0.2 amp. this = 24,000 turns. With a mean turn of 0.5 feet this is 12,200. to have 550 ω = 22.2 feet per turn. = # 28 nearest.

550 ω of # 31 B.W.G. = 5335 feet = 10,670 turns = 2,934 A.T. = 1 lb. 10 oz.

To have 4800 A.T. @ 1.5 amp = 3200 turns series wound, and to lose 25 Watts in the machine at 2.0 amp = 12.5 volts drop = 6.25 ω. 1600 feet offering 6.25 ω. 256 ft per ω. = # 18 B.W.G. 3 lbs. of wire offering 6.25 ω = 2.08 ω per lb. = # 20 B.W.G. = 810 feet = 3200 A.T.

Full sized elevation and plan of armature core.





Particulars of Maison 1/8th. HP. (Compatt) Motor.

Weight without wooden base 20 1/2 lbs. 4 delivery
With wooden base 22 1/2 "
Winding gramme-ring, and series field.
Voltage 120 at machine terminals.
Amperes loaded to delivery of 1/8 HP. 1.5
running light 0.2
Commercial efficiency at delivery of 1/8 HP. 58 %
" " " " 1/6 HP. 45 %
Speed running light 2500 revs. per min.
at delivery of 1/8 HP. 2000 revs. per min.
Dimensions
Armature body diameter, external 6", internal 4"
Number of grooves 42
Breadth of armature body over teeth, 2 3/16"
" " " " at base of grooves 1 1/32"
Cross-section of armature core 2.18 sq. ins.
Depth of grooves 9/32", breadth 0.24"
Breadth of teeth 0.21" at external, 0.05" at internal circ.
Insulation in grooves 0.008" mica at sides and oiled silk at base
Polar surface of teeth 20 sq. cms. under each pole.
Winding 630 turns, 15 layers of 10 turns each of # 27 SWG.
0.015" covered to 0.0225"
Thickness of iron strip forming core 0.030"
Commutator divisions 42.
Total length of wire on armature 1500'
Total weight " " " " 1.15 lbs.
Flat gold wire from armature to commutator
Length 3 1/2" Diameter 0.006" Resistance 1.75 ohms each.
Resistance of armature between brushes cool (incl. platinoid)
hot " " 17.75 ohms
Current in armature at full load 1.5 amperes.
Drop in armature " " 26.6 volts.
Energy expended in heating armature wire at this load 40 watts.
Magnetic flux through armature section 30,000 CGS. lines.
Induction density in core space (iron and paper) 12,760 per sq. cm.
Field magnet, of mitis cast wrought iron. Pole pieces of wrought iron in 8 segments
Core diameter 1.45" Inharflange 4".
Diameter over wire 2.28", over cover 2.33
Flux through core center at full load 120,000 CGS. lines.
Induction density in core at full load 12,120 lines per sq. cm.
Winding 450 turns of wire, 8 layers.
Wire 0.049" # 18 SWG, covered to 0.065"
Ampere-turns at light load 135, at full load 675.
Resistance of field winding 1.6 ohm cool 1.2 ohm hot.
Drop in field at full load 1.8 volts.
Energy expended in heating field wire at full load 2.8 watts
Total resistance of motor [illegible] terminals 1% cool [illegible] hot.
Brushes of copper gauze [illegible]
Fuse wire safety catch 0.014" fuses at 3 amp

Electromagnetic design for a small 100-Watt Edison motor.

Power 100 Watts 110 volts - 2 amperes maximum current.
42 grooves Each {0.7 deep / 0.24" wide} and Total breadths 2.52" 2.25

42 Commutator bars.

Armature wire #27 B.W.G. 0.016" Paper covered to 0.018".
12 wires in each layer = 0.216" insulation 0.024".
14 layers = 0.252" insulation 0.008".
168 wires per groove = 7056 wires all round. (5460 actually placed)
Breadth of core proper 0.87 cm (11/32") Allowing 14,450 lines per sq. cm gives 62,850 lines usefully developed. Cross section 2.18 sq. cms.
Speed 30 revs. per sec. = 1800 per min. = 2830' per min. at periphery
Surface of side of armature 15.7 sq. in. = 101.3 sq. cms., to each segment 2.41 sq. cms. of which 1.75 is occupied by groove leaving 0.66 sq. cms. per groove of iron, and 17 grooves will be covered by pole leaving 11 sq. cms. of iron on each side = 22 sq. cms of surface iron offered to the poles.
Clearance 1/32" (0.08). Reluctance in air $\frac{2 \times 0.08}{22}$ = 0.0072
6 cms. of iron @ 14,450 0.0060
Reluctance of armature 0.0132
Mean length of one turn on the armature 9.5 cms. = 0.31 ft.
Total length of wire 2187' = 7.75×10^{-4} Ohms. per ft. = 1.69 g.s lbs. of wire
Total res. of wire 2187×0.0016 = 2.2 ω
The next size of wire = 0.018" #26 B.W.G. covered to 0.020" gives 11 wires in one layer, and for depth 12 deep = 132 wires per groove or 5544 wires in all. The weight would be 1.75 lbs.
The length 5544×0.31 = 1720' ft.
The res. $1720 \times 0.032 \div 4$ = 13.7 ω cool or 16 ω hot.
The speed for 105 volts would be $\frac{105}{5.544 \times 6.285}$ = 30.1

The winding adopted was 130 turns per groove (13 layers of 10 turns each) #(22-27) B.W.G. 0.0188 single cotton covered to 0.0225. The resistance of each section is 1.6 ω cool. The base in the groove is of oiled silk, and the walls are lined with mica.
The field magnet 1 1/2 diam. is wound with 6 layers of 39 turns of #11 B.W.G. coil to or 234 turns in all.

The resistance of the armature cool between brushes is 14.95 ω. including the 3/4" length of platinoid

For the determination of the wire on the field magnet see p 50

The diameter of the core in the mitis iron pattern is 3.55 q.q.y.o.n
. pole uprights are 2.54 x 1.85
Interflange 10.2.
The weight of the wooden pattern is 7 oz = 199 gm
The platinoid connecting wire were 3" long first of 0.011" 0.55 ω
next 0.0073" 1.2 ω
third 0.0054" 1.6 ω

Inductance of the secondary of the large induction-coil by the method of discharge. 5th December 1890.

Source of EMF	Capacity	a	Mean throw	q per div.	
1 C.C. @ 20°C + 2 ϕ 1.4325 × 10^8	2.0 ϕ × 10^{-11}	2.865 × 10^{-7}	24.1.5	1.187 × 10^{-9}	

E.M.F.	Res: of discharge circuit	Current abs. units	Res: in cecity units of 10⁹	Total qty. of el. set free	Max. potential throw of q.	q.	Throw	Inductance abs.	Logel Henrys	Trans Henrys
3.20	30,600 Ω	1.044 × 10^{-1}	100,000 Ω	138,880 ϕ (1.385 × 10^{-10})	127	1.587 × 10^{-8}	2.668 × 10^{-2}	1.958 × 10^{10}	1958 H	1970 H
			25,000 Ω	60,850 ϕ (6.075 × 10^{-11})	278	3.30 × 10^{-7}	2.008 × 10^{-2}	1.928 × 10^{10}	1920 H.	1932 H.

Condenser voltmeter Observations made by Mr Davis in Lecture Room with the Western Thomson Dynamo.

Work of Nov. 20

Mark Obs.	Position of Instr:	Res. in circ:	Obs.	Res. of Instr. in Obs.	Total res:	Multiplying Ratio	Volts at Station	Results		Mean	±
1	Main Dynamo	7500	56	294	7794	2665	58.0	1538	86,120		
2		7000	65	297	7297	24.57	63.0	1548	101,600		
3		6000	90	306	6306	20.6	74.5	1536	138,250		
4		4000	165	340	4340	12.77	108.0	1380	224,970	1540	± 2.5
1	Exciting Chamber	7500	60	295	7795	26.43	60.0	1586	95,160		
2		7000	72	300	7300	24.33	66.0	1606	115,650		
3		6000	90	306	6306	20.61	74.5	1536	138,250		
4		4000	212	360	4360	12.11	130	1575	333,800		
			433 ω						682,860	1574	± 15

The Weights given to the individual observations are the observed no. of degrees

On the Inductance of Large Edison Field Magnets.

# of Standard Marks	Wires all round mm.	Res: per sec: at 120 v.	Calculated ϕ	Total ϕ allowing for leakage ϕ = 1.8	Weight of wire + large ones each magnet	Mean circumference	Total length on each magnet	No. of turns on both magnets	Res: of magnets cold at 12° Cent.	Current in magnets	Flux × Turns per ampère
60	16 m	6.14	1.114 × 10^7	1.71 × 10^7	405 lbs + 8 lbs	6'	4.860	16,20	17.2	7.0	4 × 10^9
C Mean	800	11.7	1.292 × 10^7	1.923 × 10^7	113 lbs + 22 lbs + 115 lbs	4.8'	68,250	27,880	24.00	0.571	9.37 × 10^{11}
Edis: S.C.M.											17.4 × 10^9

Iron wire used experimentally in circuit with a courtney battery = 625 ems: of 0.079" drawn galvanised #14 B.W.G.

Using this wire in a spiral of 64 turns, the current from the battery of 8 cells was 35 ampères with the res: all out, or 0.174 ω of which 0.014 was in leads leaving 0.160 ω or 0.02 ω p. cell.

With the resistance all in, the current fell to 9.5 ampères = 0.63 ω or 0.46 ω in the iron wire. This range appears to be sufficient.

The weight of this battery of 8 cells fully charged is 12½ lbs.

Insulators of rubber tube, were put on the copper guides on the 22nd Jan.

The total length of wire on the field magnet is 559 × 9.697 = 5415

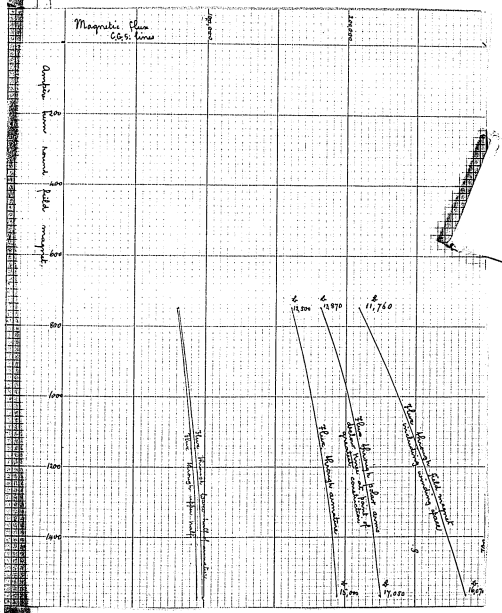
diam. of the core is 1.975"

wound are: 3.55"

Mean diam 2.713"

Mean circum 8.5" = 0.71'

= 7680 turns



Magnetic measurements with the small ½ HP Motor

8th December 1890.

5 turns of insulated wire were wound upon (1) the centre of the field-magnet (2) upon the polar arcs just below the turns (3) upon the armature between the pole both above and below, these forming independent secondary coils

Source of EMF	E.M.F.	Capy.	Q	Mean throw	ϕ per div.
1 C.E. @ 14°C	1.439×10^{8}	2.00×10^{-11}	2.878×10^{-7}	233	1.235×10^{-9}

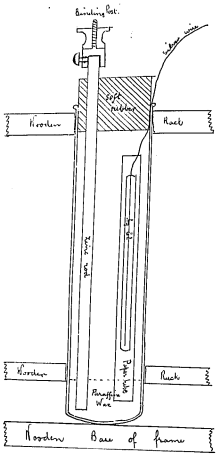
Field Current	Turns	Current Amps.	Calculated Amp. turns on field	No. of throws	Position	Mean throw	Resistance added in Ω. ckt.	Resistance of Ω. ckt.	q	ϕ	L
15°0	0·2679	0·206	1570	Field Magnet	3	227	5000	10200	2.803×10^{8}	2.84×10^{-9}	16,070
				Leg. 1	3	88					
				" 2	4	89·4	"	"		1·12 "	17,050
				" 3	4	84	"	"	1125	1·126 "	
				" 4	3	89·7	"	"		1·058 "	
				Armature	3	75·2	"	"		1·130 "	
				Cross	3	78·5	"	"		0·3479 "	14,690
										0·3880 "	15,340
11°0	0·1944	0·150	1144	Field Magnet	5	199	"	"			
				Leg. 1	4	84	"	"		2·007 "	14,090
				" 2	4	83	"	"		1·058 "	16,030
				" 3	4	79	"	"	1082	1·045 "	
				" 4	3	84·8	"	"		0·905 "	
				Armature	4	71·5	"	"		1·068 "	
				Cross	4	73·5	"	"		0·906 "	13,970
7°15	0·1272	0·098	780	Field Mag	4	166	"	"		0·926 "	14,360
				Leg 1	3	72·7	"	"			
				" 2	4	70·5	"	"		2·092 "	11,760
				" 3	3	67	"	"		0·915 "	13,870
				" 4	3	73	"	"	0900	0·891 "	
				Armature	3	63·7	"	"		0·844 "	
				Cross	3	64·3	"	"		0·920 "	
										0·802 "	12,440
										0·810 "	12,560

The cross section of the field magnet is taken at 17·8 sq. ins.
" " " " pole " " 6·6 " at the
point of greatest constriction
" " " armature core space 6·48 "

Test of pulley no 2 rewound in reverse directions alternately.
58 turns in each groove = 276 turns in all. 8. XII. 90

Run No.	Ammeter	Shunts	Current	Amp. turns	Stuffing Thickness / depth	Distance	Moment ft lbs.	Equivalent pull at one rope	Total allowing 12% for friction
1	2	0·35	1·823	501	88 lbs	8'	1446	115·2	2443
2	4	0·83	4·323	1188	26		208	166·4	294
3	6	1·13	5·885	1618	35		280	224	352
4	8	1·52	7·92	2178	38		304	243·2	371
5	10	1·85	9·636	2650	41		328	262·4	390
6	12	2·075	10·81	2973	45·5		364	291·2	419
7	14	2·3	11·98	3294	49		392	313·6	441
8	25	2·5	13·02	3580	57		456	364·8	492
9		5·5	28·65	7780	60		480	384	542

The curve is added to the sheet on page 18



Full sized vertical section of cell.

Table of Inductances of Copper wire suspended overhead

Calculated from the formula $l = (2 \log \frac{4h}{d} + 0.5)$
where h is the height above the ground, d the diameter, and l = inductance per cm.

Diameter of copper		Suspended 400 cm or 13½' above ground		Suspended 700 cm or 23' above ground		Suspended 1000 cm or 33' above ground		Suspended 1300 cm or 42½ above ground	
C.m.	Inches	Millihenrys per Kilometre	Microfarads per mile	Millihenrys per Kilometre	Microfarads per mile	Millihenrys per Kilometre	Microfarads per mile	Millihenrys per Kilometre	Microfarads per mile
0.10	0.039	1.986	3.196	2.109	3.393	2.170	3.493	2.222	3.576
0.20	0.079	1.848	2.974	1.960	3.154	2.031	3.268	2.083	3.352
0.30	0.118	1.766	2.842	1.878	3.022	1.950	3.138	2.002	3.222
0.40	0.158	1.709	2.750	1.821	2.930	1.892	3.045	1.945	3.130
0.5	0.197	1.664	2.678	1.776	2.858	1.847	2.973	1.900	3.058
0.6	0.236	1.628	2.621	1.740	2.800	1.811	2.914	1.863	2.998
0.7	0.276	1.596	2.569	1.709	2.750	1.780	2.865	1.833	2.950
0.8	0.315	1.570	2.527	1.682	2.706	1.754	2.823	1.806	2.906
0.9	0.354	1.547	2.489	1.659	2.669	1.730	2.785	1.783	2.870
1.0	0.394	1.526	2.456	1.638	2.635	1.709	2.750	1.761	2.834

Tests and data of the 10th Dec. 20. new model Edison Silver-Chloride cells.

5 oz. of Ag Cl. were melted and 10 plates were cast in glass tube ½" diam. The total weight of castings with silver wires being 64.5 gms. The weights of the different parts of the cell are:-

Glass tube	30 grammes
Rubber stopper	16.8 "
Zinc rod	15.5 "
Binding post	7.0 "
Ag + Ag Cl plate	7.5 "
	76.8
Solution @	40
	116.8

Weight of one cell complete 116.8 The weight of a sample was 1214.5 g.

The E.M.F. of the battery of 10 cells was	10.13 volts	1.013 p.c.
internal res. " " " "	168 ω	16.8 "
E.M.F. of the first 5 cells was	5.13 "	1.026 "
internal res. " " " "	62 ω	12.4 ω "
E.M.F. " " second " "	5.0 "	1.00 "
internal res. " " " "	105 ω	21 ω p.c.

Particulars of different ½ H.P. motors by various manufacturers

No. of Make	Maker.	Date of Price List	Weight	Speed.	Pulley diam.	Pulley face	Floor space	List Price	Discount
1	Edwin M.W.	1889	130	1900	2 5/8"	2"	20 x 17 3/4	$ 130	
2	Bunnell & Co	11th Mar 20	-	-	-	-	-	$ 130	25 & 20
3	J.B.L. & Co	1820	-	-	-	-	-	$ 130	
4	Connecticut	1820	150	2000	3½"	2	11½ x 17	$ 130	
5	Daft	Mar 1820	85	2,900	3	2	16 x 12	$ 140	
6	Eddy	1889	142	2,100	3½	2¼	"	$ 130	
7	N.Y.E.Mfg Co	1820	-	-	-	-	-	$ 130	90%
8	Perot	1889	70	2000	2½	1¾		$ 130	
9	Ritter	1889	-	2400	3	2		$ 120	
10	Detroit	1890	114	2200	3	2		$ 130	
11	Edison	1890	36	$\frac{1750}{3500}$	2¼	1½"	7" x 8½"		

Magnetic experiments with a permanent magnet.

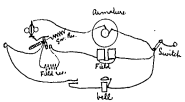
A horse shoe magnet, of the dimensions shewn was made of tool-steel. Upon its extremities shoes were forced carrying two disks facing each other on arms sliding through the shoes.

Experiment no 1. The magnet was wound with 320 turns of # 12 B.W.G. the disks brought into contact, the magnet excited with perhaps 50 amperes, for about 1 minute, and the residual magnetism then tested by separating, and uniting the two disks while the induced current through the wire was observed on the ballistic galvanometer.

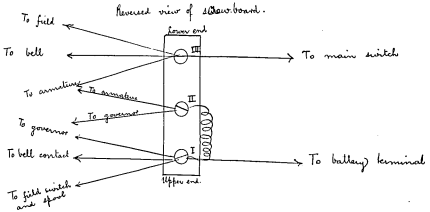
No. of Obs.	Source of EMF	E.M.F. + Log$_{10}$	q	Mean Throw	q per div.
6	1 B.B. @ 15°C	1·438 2^{9}	$2{\cdot}976\times10^{-7}$	231·5	$1{\cdot}242\times10^{-9}$

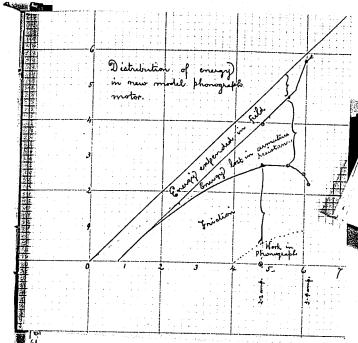
No. of Obs.	Res. in ext. with G	Res. of G. coil.	Mean Throw (by opening & closing magnet)	q	φ	Section of magnet sq. cm.	L.			
7	0	8200 ω	64	$7{\cdot}952\times10^{-8}$	$\frac{4\cdot135\times10^{11}}{320} = 1{\cdot}29\times10^{8}$	1·98	65			

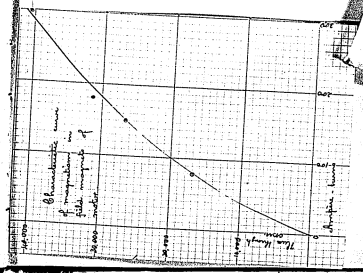
Diagram of Connections



Reversed view of slate board.







Electrical Data of New model Battery Phonograph.

The new model has a cast iron field magnet, but the same model of armature as heretofore. The weight of the whole machine is 44½ lbs. It has a bell added to it, and it varies its speed from 50 to 230 revolutions by the governor and a resistance coil in the field magnet circuit.

The particulars of the various parts are as follow:-

Resistance of	leads from battery	0.02 ω
-	- 4 field coils in series	5.67 ω 3.185
-	- field resistance spool german silver	10.14 ω
-	- armature	
-	- german silver shunt on governor	2.485 ω
-	- bell	2.33 ω
Inductance of	bell $\frac{1000}{100}$ 4.001 ω 0.286 ℙ =	11.4 h.
-	- field - 17.757 ω 3.58 ℙ =	0.636 H

The following measurement was made of the magnetic flux through the field:- 18 turns of secondary wound the center of one field.

No. of Obs.	Current through Obach	Current	Field $\frac{4\pi NI}{10}$ A. T. per c.m. Coil	Mean throw	Resistance of G. Inc. ext.	R. of G.	Value of 1 div. q_1	$\frac{q_0}{q_{10}}$	$\frac{q_0}{q_{20}}$	L
1	0.100	0.522	300	62.25	0	5250	1.242×10^{-3}	7.73×10^{-3}	40,570	5,070
2	0.060	0.313	180	48	-	-		5.96 -	31,300	3,815
3	0.050	0.261	150	41	-	-		5.09 -	26,700	3.340
4	0.026	0.136	78	26	-	-		3.23 -	16,960	2,120

When running at full normal speed the armature makes 3.75 revs. per second with a current of 2.4 ampères through it reducing the pressure by 0.8 volt, while the terminal p.d. was 2.0 volts so then

$3.75 \times 108 \times q = 1.2 \times 10^8$

$q = \frac{1.2 \times 10^8}{4.05} = 30,000$ approximately.

No. of Obs.	Revs. of Cylinder	Work.	Obach	Current amperes	R.D. at m.t. volt	Energy absorbed	Current in field	Energy absorbed in field	Current in armature	disp. in armature	Watts in armature
1	50	nil	0.425	2.218	2.140	4.75	0.378	0.809	1.840	0.64	2.82
2	144	-	0.520	2.713	2.052	5.57	0.362	0.763	2.350	0.78	2.82
	230	-	0.620	3.236	1.844	5.97	0.317	0.216	3.628	1.014	2.60
	-	reproducing	0.65	3.390	1.80	6.11	0.314	0.205	3.276	1.09	2.33.

Electrical Measurement of Power absorbed by the operation of a magnetic belt. 10th December 1920.

A no. 4 motor was belted to a pulley on the same shaft as the magnetic pulley 8" in diam., whose behavior is given on page 23. One belt rested on this and passed over a large 23" diam. magnetic pulley fairly tight.

At 2014 revs. per min. of 23" pulley: 1290' per min. the Express motor took 26.86 amperes at 52 volts = 1380 Watts

At 280 revs. per min: = 1758' per min: the motor took 70.8 amperes at 69 volts = 4885 Watts when the small magnetic pulley was excited, a difference of 3505 Watts @ 75% efficiency = 2680 Watts lost in magnetic friction.

By a lever test, the moment of magnetic and mechanical friction required to move the magnetised small pulley was 28 foot x lbs.

On the 11th December, the experiment was repeated with small 4½" pulley from Schenectady which was wound right and left alternately, used in conjunction with a large magnetic pulley. The energy absorbed in magnetic friction over and above mechanical friction when running at 900 feet per minute was

1000 Watts with the belt fairly tight
1500 " " half ems: loose
2000 " " 5/8th contact loose.

Test of a sprocket chain having link pins 3/32" diameter.

#4 motor driving, and absorbing 70 amperes @ 120 volts = 8400 watts

Prony brake 450 revs p.m. 15 lbs. wt at 8 feet radius

50.27 x 7.5 x 15 x 0.737 = 7670 Watts

The pull upon the belt running on a 12" pulley = 240 lbs.

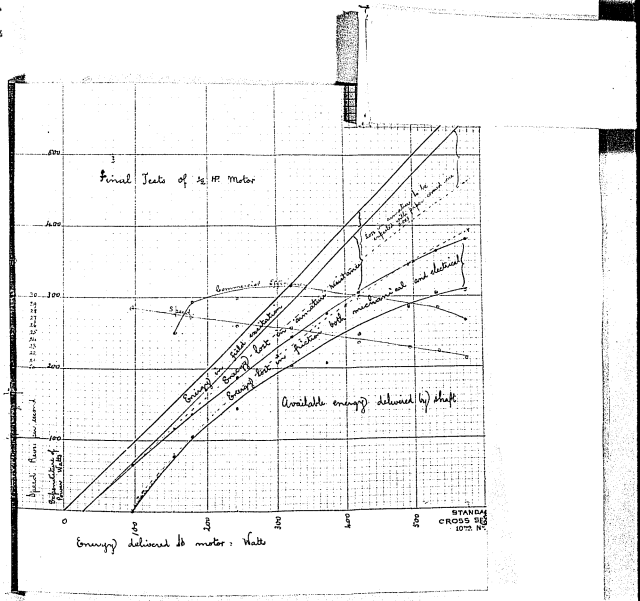
Test of the breaking stress of 1" 3 = strand Manilla rope.

#40 spring 375 lbs indicated. Piston area 77.06 = 2890 + weight of piston (100) = 2990 say 3000 lbs. weight.

No. of Obs.	P.D. on motor	Ohmic	Current in motor	Energy in motor = Watts	Current in field	Energy in field = Watts	Current in armt.	Energy in armt. = Watts	Ω	Loss of energy in armt.	Watts left for field in motor	Energy in useful work developed in armt.	P.D. across armt.
1	122·5	0·013	0·224	27·4	0·224	27·4	0·089	–					
2	"	0·150	0·783	96·0	"	"	0·559	68·5	0·312	2·6	4·68	65·9	117·84
3	"	0·243	1·252	153·4	"	"	1·023	125·4	1·057	8·8	8·56	117·1	112·94
4	"	0·278	1·451	177·8	"	"	1·227	150·3	1·506	12·5	10·22	137·8	110·88
5	"	0·378	1·973	241·7	"	"	1·749	211·2	3·059	25·5	14·87	188·8	107·93
6	"	0·498	2·600	318·5	"	"	2·376	291·1	5·645	47·0	19·79	244·1	102·57
7	"	0·580	3·027	370·8	"	"	2·803	343·4	7·857	65·5	23·35	277·9	99·15
8	"	0·655	3·418	418·8	"	"	3·194	391·3	10·202	85·0	26·61	306·3	95·89
9	"	0·769	4·012	491·5	"	"	3·788	464·0	14·349	119·5	38·86	344·5	90·94
10	"	0·832	4·342	532	"	"	4·118	504·5	16·958	141·3	34·31	363·2	87·19
11	"	0·900	4·697	575·4	"	"	4·473	548·0	20·008	167·3	37·26	380·7	86·24
12	"	0·870	4·540	556·2	"	"	4·316	528·8	18·628	155·2	35·96	373·6	86·82

Weight of Motor complete 36 lbs. = 72 lbs. per H.P. = 100 lbs per kwt.
Power with present winding 200 Watts @ 300 Watts intake = 66⅔ eff.
300 . @ 500 . . = 60%.
expected with paper cond wire 300 . @ 420 . . = 70%.
400 . @ 600 . . = 66⅔.
expended in the field magnet 30 Watts
. . friction 40 to 65 Watts.
Armature unwound weight 6 lbs. Weight wound 8 lbs.
42 sections, each 24 turns 7 layer of 7 turns of # 26 BWG
0·018" d.c.c. to 0·029". With paper covered wire # 23 BWG.
0·025" covered . 0·028". Present res: warm including platinoid wire 8·83 ω. Paper cond. wire 4·33 ω.
Cross section of core 1"×1". Grooves 0·225" broad and 0·225" deep
Field magnet. Diameter 1⅞" wrought iron. Wound with 3 lbs: of # 31 BWG. 0·010" Res. 550 ω. = 1·7 lbs. of copper wire. Res: warm 600 ω.
Speed 1780 revs. per min running light
1300 . . . at full load.

Flux through field magnet 250,000 = 16,000 per sq. cm.
. . wrought iron polar extensions 225,000 = 17,000 per sq cm.
. . armature 190,000 = 15,000 per sq. cm. through core space.


Trial Tests of ½ H.P. Motor
Commercial Efficiency
Energy in field windings
Energy lost in friction, both armatures and shaft
Energy lost in friction both armatures and shaft and electrical
Available energy delivered by shaft
Energy delivered to motor, Watts
STANDARD CROSS SECTION NO.

Final Test of the Edison & H.P. motor before sending off the model

11th December 1820 Rec. of arm: 8.33.

Revs: per min.	Revs: per second	E.M.F. per rev. per sec.	Scale	Reading	Torque	Energy delivered 6165	Energy in Cables	Int. & Ext. eff. of motor	Mech. eff. of motor	Remarks.
-					-	-				Current in field
1710	28·5	4·13			-	-	65·9	68·6	~~50·6~~	Motor running light
1660	27·67	4·08	200 @ 20 50 @ 11		4850	77·6	39·5	76·3	50·6	Driving dynamo light
1640	27·33	4·07	500 @ 10 50 @ 23·5		6175	104·1	33·7	77·5	58·55	- dyn. arm. thro s.c. field
1558	25·97	4·16	500 @ 15 200 @ 5 50 @ 82		8910	142·7	46·1	78·14	59.03	1 lt Lamp on dynamo
1537	25·61	4·00	500 @ 20 200 @ 10 50 @ 16·7		12,835	202·6	41·5	76·65	63·60	2 - - - -
1430	23·83	4·16	1000 @ 10 200 @ 20 50 @ 7		14,150	207·9	70·0	74·96	56·07	3 - - - - -
1410	23·50	4·08	1000 @ 20 200 @ 5 50 @ 30·5		17,150	248·5	57·8	73·14	59·34	4 - - - - -
1370	22·83	3·98	1000 @ 22 200 @ 11 50 @ 43		20,165	283·9	60·6	70·1	57·8	5 - - - - -
1330	22·17	3·93	1000 @ 20 200 @ 5 50 @ 24		22,200	303·5	59·8	68·26	57·1	6 - - - - -
1275	21·25	3·99	1000 @ 22 200 @ 10 50 @ 42		23,425	307·0	73·7	66·16	53·35	7 - - - 9·30 ante
1325	22·08	3·92	1000 @ 22 200 @ 12 50 @ 84		22,810	310·5	63·1	67·20	55·84	7 - - - Noon.

The temperature of the armature at noon was about 12.5° F.

The wire on this armature is 0·016" covered to 0·029". D.C.C.
(allowing) 0·028" and 0·003 for paper covering gives 0·025" or
23 B.W.G. which has 625 c.mils instead of 324. The res. of the
armature would be 4·33 instead of 8·33.

Required the best winding for an oxc. milling analysis magnet for Mr Batchelor, to use with a Lalande battery of 4 cells.

The core is to be 6" long (5·75" or 14·6) between flanges, and 1½" (3·18) in diam. The external diamatir to be 2·75" (7)·. The current to be 3 amperes, and the emf. (4 × 0·75 − 3 × 4 × 0·084) = 2·5 volts so that the resistance is to be 0·83 ω.

$$d + t = 0.0392 \sqrt[4]{\frac{\pi}{T}}$$

The coiling space is $14{\cdot}6\ (38{\cdot}5 - 7{\cdot}94) = 14{\cdot}6 \times 30{\cdot}56 = 446.2$

$$= 0.0392 \sqrt[4]{\frac{446.2}{0.83} \times 10^4}$$

$$= 0.0392 \sqrt[4]{53760}$$

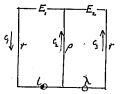
$$= 0.0392 \times 8.56$$

$$= 0.3356 \text{ cms diam} = 0.132" \text{ less } 0.015 = 0.118"$$

= # 11 B.W.G.

This has a resistance of 0·01¶ ω per ℔.
and for 0·83 ω, 14·88 lbs. will be required. Say 5 lbs.

On the solution of problems in 3-wire distribution



The equations of motion may be written $E_1 + E_2 - c_1(r+l) - c_3(r+\lambda) = 0$

$$E_1 - c_1(r+l) - c_2(\rho) = 0$$

$$c_1 - c_2 - c_3 = 0$$

Or in determinant form

c_1	c_2	c_3	
$-(r+l)$	-0	$-(r+\lambda)$	$= E_1 + E_2$
$-(r+l)$	$-\rho$	0	$= E_1$
1	-1	-1	$= 0$

$$\therefore c_1 = \frac{(E_1+E_2)\rho + (E_1+E_2)(r+\lambda)}{-\rho(r+l) + (r+l)(r+\lambda) + \rho(r+\lambda)} = -\frac{E_1(\rho + r + \lambda) + E_2\rho}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

$$c_2 = \frac{E_1(r+l) + E_1(r+\lambda) + (E_1+E_2)(r+l)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)} = -\frac{E_1(r+\lambda) - E_2(r+l)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

$$c_3 = \frac{(E_1+E_2)(r+l) + \rho(E_1+E_2) - E_1(r+l)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)} = -\frac{E_1\rho + E_2(r+l+\rho)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

Let $E_1 = E_2 = 125$ $\quad r = 0.025$ $\quad l = 0.1$ $\quad \lambda = 0.111$ $\quad \rho = 0.05$

Then $c_1 = \frac{125\ (0.136)}{0.05 \times 0.286 + 0.125 \times 0.136} = \frac{17 + 12.5}{0.01305 + 0.017} = \frac{29.5}{0.03005} = 981.8$

$$c_2 = \frac{125\ (0.011)}{0.05 \times 0.261 + 0.125 \times 0.136} = \frac{1.375}{0.03005} = 45.8$$

$$c_3 = \frac{125\ (0.125)}{0.05 \times 0.261 + 0.125 \times 0.136} = \frac{15.625 + 13.5}{0.03005} = \frac{28.125}{0.03005} = 936.0$$

The pressure on l = 98·18 and on λ = 104·0
loss in r_1 = 24·54 in r_2 = 23·40 in ρ 2·29

On the activity of the average human being.

The amount of carbon administered to the average adult male daily is 4500 grains, according to the statement in the "Chemistry of Common Life". This is 0.7 lb and = 318 grammes. The heat energy of combustion of one grammes of carbon with oxygen forming CO_2 is 3.36×10^4 ergs, so that the heat energy absorbed daily is 1068×10^4 ergs or 1068×10^7 joules. The number of seconds in one day is 8.64×10^4 so that the average rate of absorbing power is $\frac{10.68 \times 10^6}{8.64 \times 10^4}$ = 123.6 Watts (during 10 hrs, or 307 lbs in 24 hrs)

The average rate of working is stated to be 73.7 Watts, and the total work stated to be done by a laborer daily is 2.65×10^6 joules. This represents a total commercial efficiency of 0.248. Of the carbon taken in 201.6 grms are said to be exhaled through the lungs daily as 739.3 grms of CO_2 this represent a work of 6.77×10^6 joules.

Tests of a Sample of hard drawn copper wire for The Engineering Department.

This sample was received on the 13th December, was #4 B.W.G. and about 150 feet in length. The following measurements were made of its diameter, at points 3' apart in a length of 72 feet.

Number of Obs.	Diameter Inches.	Mean	v	v^2	Result	Cms.
1	0.2380		0.0003	9×10^{-8}		
2	0.2376		0.0001	1		
3	0.2376		0.0001	1		
4	0.2373		0.0004	16		
5	0.2377		0.00			
6	0.2376		0.0001	1		
7	0.2374		0.0003	9		
8	0.2379		0.0002	4		
9	0.2378		0.0001	1		
10	0.2379		0.0002	4		
11	0.2380		0.0003	9		
12	0.2377		0.			
13	0.2379	0.2377	0.0002	4	0.2377 ± 0.00003	0.6038.
14	0.2379		0.0002	4		
15	0.2379		0.0002	4		0.2854 sq. mm.
16	0.2378		0.0001	1		
17	0.2378		0.0001	1		
18	0.2379		0.0002	4		
19	0.2377		0.			
20	0.2377		0.			
21	0.2378		0.0001	1		
22	0.2378		0.0001	1		
23	0.2376		0.0001	1		
24	0.2377		0.			
25	0.2376		0.0001	1		
	1811			77×10^{-8}		
	.23736					

122. cms of this wire weighed in air 308.235 grms. = 2.526 grms per cm. = 40066 grms per mile = 89.62 lbs. per mile. Sp.g. 8.82

Test of Sample Hard drawn Copper Trolley wire contd:

Five lengths of wire were measured off for a test of the conductivity, in two trials as follows:-

No. of Obs:	Point	1st Obs:	2nd Obs:	Mean	Length of section tested	Section Number	Length	
1	1	302.7	302.8	302.75	1944.4	1	2247.15	
2	2	590.0	590.1	590.05	1657.1	2	1944.4	
3	3	854.5	854.5	854.5	1392.65	3	1657.1	
4	4	1139.	1139.	1139.0	1109.15	4	1392.65	
5	5	2068	2014.7	2014.9	232.25	5	1109.15	
6	6	2247.2	2247.1	2247.15	-	6	232.25	
					7 1 4 8 3 5			
					4 9 0 1 2			
					6 3 3 4 · 5 5			
					1 1 3 5 · 0 8			
					4 9 0 0 · 5 3			

Conductivity Test Res: of A+B 2707ω + 2693ω per coil.

No. of Obs:	Length of coil tested	Standard	Res: at temp:	Res: added	Ratio	Res: of wire	Res: per c.c. std	Mean Resistivity
1	2247.15	0.01ω	22°c.	1150ω bwire	1.1420	0.00139576	1779	
2	1944.4	0.009781ω @ 0°C.	0.009827	624ω	1.12255	0.0012045	1774	
3	1657.1			120ω	1.01430	0.0011250	1772	1775
4	1392.65			355ω Std ω	0.8796	0.0009864	1785	@ 22·5°c temp: of air
5	1109.15			1155ω Std ω	0.6974	0.0007852	1772	= 97.78 % cond: of pure soft copper affords a resistivity of 1598
6	232.25	copper rod 273·9 cms between electrodes mercury 0.2647cm dia 3267 q cms	equivalent length of 0.254 sq cm 2707 2693 cms	0.	1.			

Res: per cm. 5·70ω microhms @ 0°C. = 0·915 ω per mile @ 0°C. = 1·003ω @ 22·5°C.

Resumé.

No. of Obs:	Mean resistivity	v	v²	Σv²	r.	Result	Resistivity of pure copper @ 0°C	Standard at 22·5°C	Temp Coeff:	Ratio	% Cond:
5	1778	4	16	39	0·7ω	1775±0·7ω	1598 Ω	1735·3	0·00388	0·9778	97.78 ±0.08
		1	1								
		3	9								
		2	4								
		3	9								

By Matthiessen's standard this is 100% cond: of pure hard copper.

Breaking stress test

No. of Obs:	Pressure in cylinder	Area of piston sq in	Total pressure lbs:	Weight of piston lbs	Total Breaking stress	Area of wire	Breaking stress per sq in:	
1	31 lbs	77·056	2388	100	2488	0·044438	56,066	
2	31 "		2388	100	2488			

In three trials on the lathe, with one end of the wire free to move in the direction of the axis, the number of twists obtained before breaking was 22 twists in 12 inches.

$\frac{2693 + 1150}{2707} = \frac{3843}{2707} = 1.4227$

$\frac{2693 + 624}{2707} = \frac{3317}{2707} = 1.2255$

$\frac{2693}{2707 + 1155} = \frac{2693}{3862} = 0.6974$

$\frac{2693 + 130}{2707} = \frac{2823}{2707} = 1.043$

$\frac{2437 + 355}{2693} = \frac{3062}{2693} = 1.137$

$0.00388 \times 22.2 = 0.08612$ Tent. $1598 \times 1.08612 = 1735.3$

Calibration of an alternating current ammeter intended for the purposes of electrolysation.

This was an Edison ammeter from the Newyork Works, indicating up to 10 amperes. To make it more dead beat, a vane of mica about 1" square was set in a circular sector box of brass. The indications to alternating currents were found to be about half those of continuous currents. On this account the solenoid which consisted of two layers had to be exchanged for one of five layers. The calibration was effected by means of the Siemens alternating dynamo, and the Siemens dynamometer. With the latter, the following readings were obtained on the 124 volt circuit:–

No. of Obs.	Watch	Amperes	Observed Deflection	Sq: root of Deflection	Constant	Mean	v^2	v^2	Result
1	1·63	8·504	88·5	9·42	0·9026		6.3×10^{-3}	39.69×10^{-6}	
2	1·81	9·444	106.5°	10·32	0·91148	0·9089	5.9×10^{-3}	34.81×10^{-6}	0·9089
3	1·90	9·912	118·8°	10·90	0·90914		$0.5^- \times 10^{-3}$	0.25×10^{-6}	±0·00214
					27·2685			74·75 ÷ 3 terms	
					·9089				

The following observations were then made with the Siemens alternator making from 2025 to 2140 revs per min. (135 ~ to 142·7 ~ per sec)

No. of Obs.	Length of Sec. Wound round core	Dynamometer Reading	Sq: Root of Reading	0·9089 × Col 4 = effective current Amperes	Ramps in cols.	Δ chord	Δ amp	Δ chord / Δ amp.	Positions & Chords of integrations
1	8·95	73·0	8·66	7·87	19				
2	8·45	52·5	7·25	6·59	18	0·50	1·28	0·3907	7.5 8·80
3	8·175	45·0	6·71	6·099	17	0·275	0·49	0·561	7.0 8·67
4	6·85	27·0	5·20	4·727	15	0·325	1·372	0·966	6.5 8·40 / 6.0 8·075
5	5·80	20·3	4·50	4·090	13	0·05	0·637	1·648	5.5 7·495 / 5.0 6·80
6	5·15	16·6	4·075	3·704	12	0·65	0·386	1·684	4.5 6·03 / 4.0 5·685
7	4·25	13	3·606	3·278	11	0·90	0·426	2·113	3.5 4·73 / 3.0 3·80
8	3·60	10	3·163	2·875	10	0·65	0·403	1·613	2.5 3·45 / 2.0 2·19
9	2·60	6·2	2·49	2·263	9	1·0	0·612	1·633	1.5
10	2·0	4·5	2·12	1·927	8	0·6	0·336	1·786	
11	8·9	69	8·307	7·551	18				
12	8·25	47	6·856	6·231	16	0·75	1·320	0·568	7.5 8·87
13	7·85	40·75	6·384	5·803	14	0·4	0·428	0·934	7.0 8·69 / 6.5 8·03
14	6·45	23·25	4·822	4·383	12	1·4	1·420	0·986	6.0 7·67 / 5.5 7·05
15	5·2	17·2	4·148	3·771	10	1·25	0·612	2·043	5.0 6·55 / 4.5 6·05
16	3·6	10	3·163	2·875	8	1·6	0·896	1·786	4.0 5·25 / 3.5 4·73
17	2·75	6·8	2·609	2·371	6	0·85	0·504	1·687	3.0 3·95 / 2.5 3·45
18									2.0 2·90

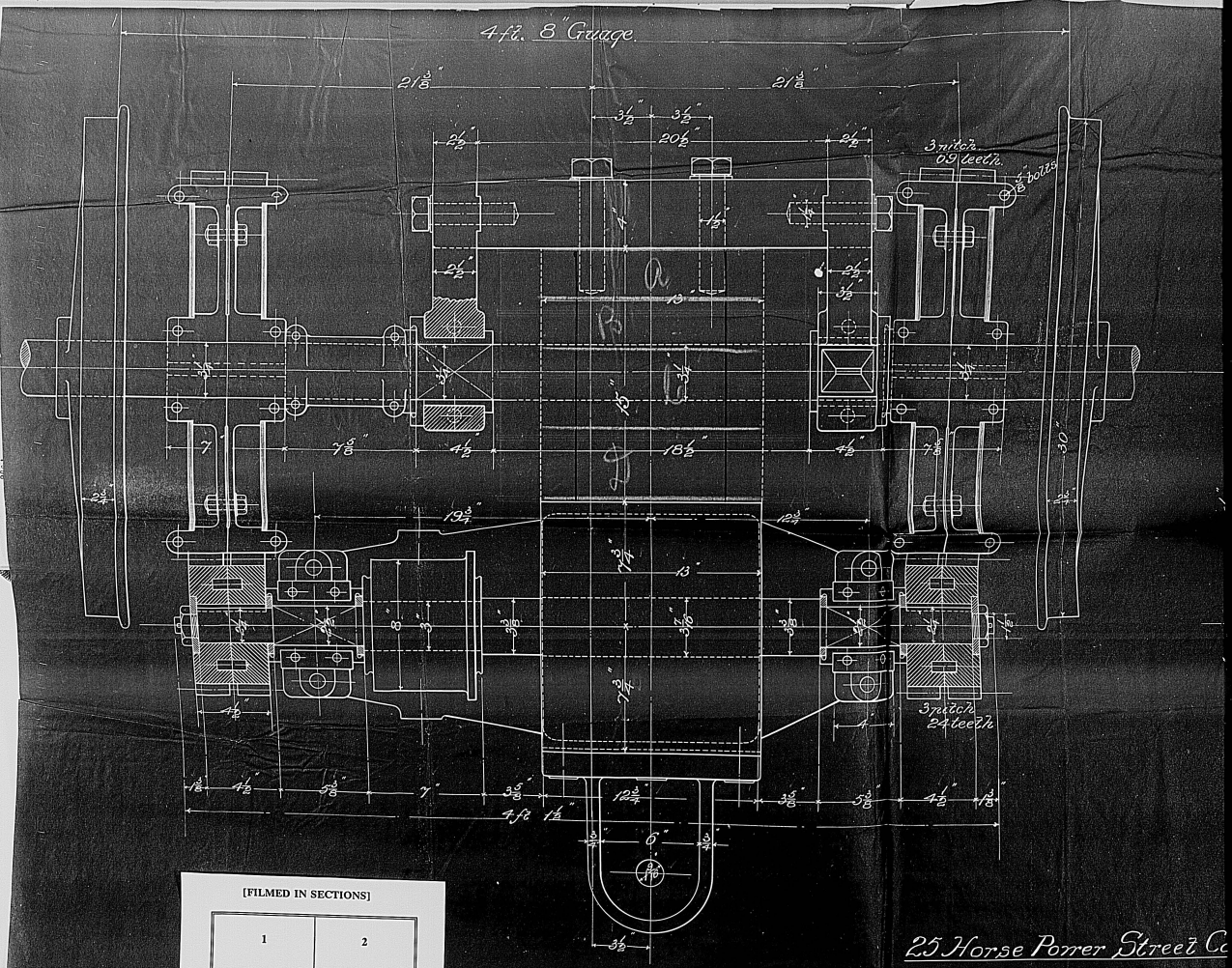
From these readings the chordal distances to the integers reckoned from the zero point are:– (radius 16·7 cm)

	7·5	7·0	6·5	6·0	5·5	5·0	4·5	4·0	3·5	3·0	2·5	2·0	1·5	1·0	0·5
	8·84	8·64	8·44	8·05	7·72	7·475	6·6	5·68	4·74	3·8	3·0	2·2	1·65	1·1	0·55
Set at:	8·8	8·65	8·35	8·05	7·65	7·15	6·5	5·65	4·73	3·9	3·0	2·25	1·7	1·13	0·55

Resistance of the instrument 0·09 ω. Inductance at zero 0·65 h. at full load 1·07 h.

The impedance at full load and 130 ~ = 0·82 ohms.

With this scale inverted, the instrument indicated 5·3 amperes for 2 amp continuous c.
4·5 " " 3 " " "
5·8 " " 4 " " "

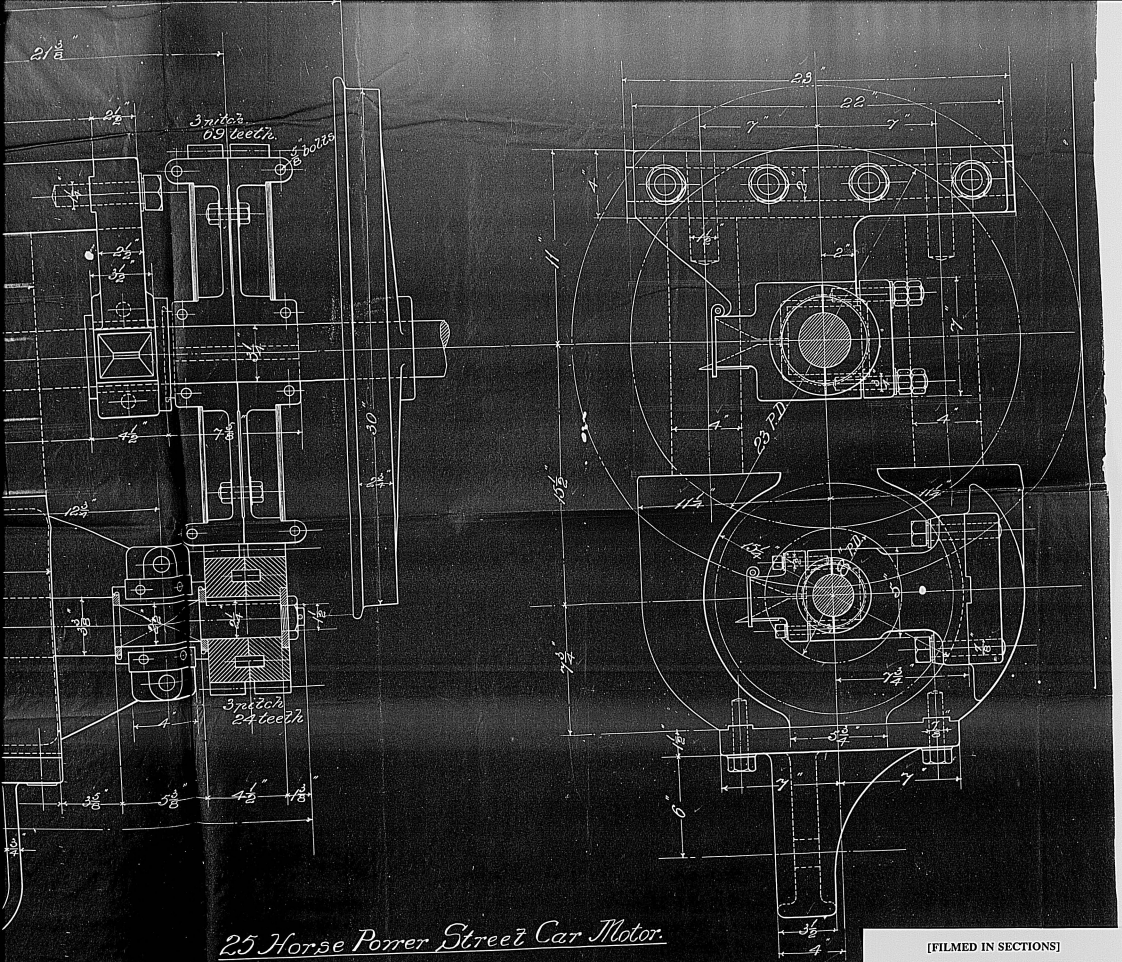


[FILMED IN SECTIONS]

1	2

25 Horse Porrer Street Co

Dec. 12. 1890



25 Horse Porrer Street Car Motor.

Dec. 12. 1890

[FILMED IN SECTIONS]

1	2

Calculations concerning a 25 H.P. street Car Motor whose blue print and description was received from the Engineering Department on the 18th December 1820.

This motor is of the Sprague general type, and gears directly to the car wheel axis with a velocity ratio of 28/8.
Speed of motor estimated for 800 r.p.m. corresponding to 24.1 m.p.h.
Core of field-magnet 8½" wide by 4" thick. Presumably elliptical.
Assuming 30 sq. in. = 193.5 sq. cms. of cross-section at saturation limit of 18,000 = 3,480,000 lines C.G.S. of which allowing 40% for leakage 2,090,000 will be useful.
The slowest speed will probably be 8 m.p.h., not greater.
This represents 89.6 revs. p.m. of car wheel, or 311 r.p.m. of car motor = 5.2 revs. per second.

$$\therefore w = \frac{500 \times 10^6}{2.09 \times 5.2 \times 10^6} = \frac{50 \times 10^3}{10.87} = 4600.$$

The winding space on the armature is 0.4" deep and 44° peripherally. = 1.76 sq. in. The space per wire is thus 0.00383 sq. in = 0.0617" diam. covered. 6 Layers would give 0.066" and 660 turns = 3960 turns in all. 7 Layers would give 0.057" and 748 turns = 5236. The greater number must be selected. The diameter of bare wire would be 0.010" less than 0.057" = 0.046". = #17 B.S. the nearest size 0.045". With 2048 c. mils.
900 c. mils per ampère are called for = 227 ampères
Double this current or 4.5 amperes will be the full load. That is 2270 Watts. The torque at unit radius with this current would be 2,090,000 × 4500 × 4.5 ÷ 6.3 = 6.72×10^5 dynes: = 6.80×10^5 gms = $\frac{6.80}{453.6} \times 10^3$ gms = 1.499×10^3 lbs = $\frac{15,000}{10}$ at the pitch line, this is 15000 lbs., and at the axle $\frac{28}{36}$ of this or 115 lbs.
The surface of the field coils is about 3600 sq. cms. each. and it is proposed to expend 2500 watts in each at full load. This represents $\frac{25}{36}$ = 0.7 Watts per sq. cms.

See also p. 82

Classification of small sizes of motors as arranged with Mr Henderson 20th December 1820

Watts	HP equivalent
100	0.13
200	0.267
400	0.53
800	1.077
1400	1.78
2000	2.7

Classification suggested by Mr H. Ward Leonard in letter 27th Dec. 20.

187	Watts	¼ HP	or in Watts 50
94		½ HP	100
375		¾ HP	200
750		1 HP	1000
1875		2½ HP	2000
3750		5 HP	4000
5625		7½ HP	6000
7500		10 HP	8000

Calculation of the breadth of grooves in a Pacinotti tooth armature of ring type.

Let R = the external radius of the core (cms)
r = " internal " " " "
d = " depth of the core (cms) = $R - r$
n = " number of grooves
b = " breadth of each groove (cms)
s = " distance between the polar extremities measured along the core (cms)
φ = " total flux c.g.s
$\mathfrak{B}$ = " permissable density in the teeth
and $\frac{\varphi}{\mathfrak{B}} = a$ the active tooth surface

Then $2\pi(R^2 - r^2) = 2\pi(2dr + d^2)$ is the total surface of core
Of this $2nbd$ = groove surface.
and $4sd$ = inter polar surface.

$$\therefore \frac{2\pi(2dr + d^2) - 4sd - 2nbd}{2} = \frac{\varphi}{\mathfrak{B}} = a$$

$$\therefore a = d(\pi r + \pi d - 2s - nb)$$

$$\therefore b = \frac{1}{n}\left\{\frac{1}{d}2\pi r + \pi d - 2s - \frac{a}{d}\right)$$

$$= \frac{1}{n}\left\{\pi(2r + d) - 2s - \frac{a}{d}\right\}$$

Calculations for a small motor of 800 Watts delivery at 110 volts terminal p. d.

Allowing 200 watts to be consumed in friction, the armature must transform 1000 Watts into mechanical effort. Allowing 20 volts drop in the armature at full load, the current will be 11.1 amperes, and the resistance between brushes (hot) = 1.8 ω. Of this allowing 15% for platinoid = 0.27 ω, the remainder (1.53 ω) is the resistance of the armature proper (hot). The resistance of one section, assuming 142 is 0.11460 (hot) = 0.1170 cool.

Allowing a total flux of 800,000 lines and a density of 15,000 = 20 sq: cms: total cross section or 10 on each side. With a square core, this is 3.163 cms. square = 1.25". With an external diameter of 7", this means an internal diameter of 4.5" (17.78 0 = 55.87 & 13.49 0 = 42.39).

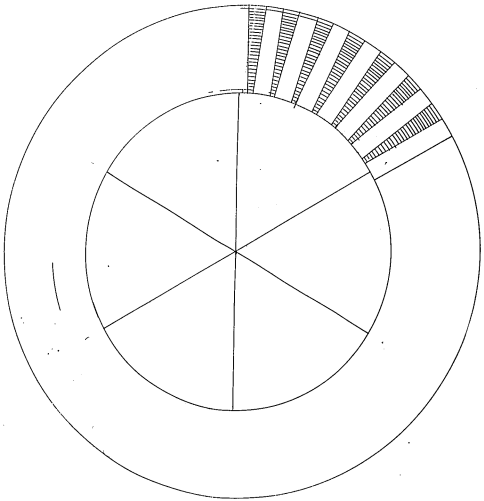
By the above formula, allowing an interpolar distance $s = 5$, and $\mathfrak{B} = 13{,}000$ we have $a = 23.1$ $d = 3.16$

$$\therefore b = \frac{1}{142}(3.14 \times 14.5 - 10 - 7.3)$$

$$= \frac{1}{142}(45.8 - 17.3) = \frac{1}{142}(28.5) = 0.678$$

The limiting breadth is found by $b = 25.99 - 142 \times 0.16 = 25.99 - 6.72 = 19.27/42 = 0.695$ = $0.27\frac{1}{4}$" say 0.25".
Allowing 0.02 for insulation, leaves 0.23 winding space breadth.
The mean turn will be 8" = 0.667'.
The speed being 1700 revs: p.m. light = 28.3 p. second.
The number of wires needed all round will be $\frac{107 \times 10^6}{28.3 \times 8 \times 10^3}$

$= \frac{107}{226} \times 10^3 = 1260 = 30$ per groove.



Thirty turns will make 20' having 0.117" ∅, so that the wire must have 0.00585" per foot cool = #19 B.W.G. 0.042". If this be covered to 0.050", there will be room for five turns per layer. Allowing 0.010" for body insulation, and 0.007" for spaces above, the depth of groove must be 6 × 0.050 + 0.017 = 0.317". The total breadth of core will thus be 1.25 + 0.634 = 1.884"; 8.40' = 8.4 × 5.3/4 × 15" = 24.5 lbs.

The total cross section of the armature being 20 sq. cms. the cross section of the core should be 20 sq. cms. = 6.18 cms diam. = 2.444" say 2.5".

Winding for 500 volts:- The winding space being 0.3" × 0.25" and 120 turns being needed per groove (10 × 12) the covered diameter of the wire = 0.025" and bare 0.018" # 26 B.W.G. 12 layers of 10 turns each.

Winding for 2500 volts:- the covered diameter must be 0.707 × 0.050 = 0.0353" = 0.028" bare = # 22 B.W.G. 56 turns. 8 layers of 7 turns each.

The diameter of the mitis iron pattern core is 6.7 (2.67") 35.25 sq. cms.
The polar extensions 4.45 × 3.90. The Interflange 11.6
Weight of the pattern 922.5 gms.

The size of wire employed in the 500 volt winding is 0.018" cond. to 0.023". The resistance of one block is 0.78∞ for lower half and 0.98∞ for upper half @ 18°C. each 6 layer of 50 turns.

The weight of the armature body, grooved and ready for winding is 9 lbs 13½ oz. including spider which is. 1 lbs 11½ oz.
The weight of the field iron is 47 lbs. (wrought iron)
The weight of the motor with pulley when completed with 500 volt arm on the 24th January was 79 lbs.
The weight of wire on the 500 volt arm was 2 lbs 11 oz.
" " " " 120 " 3 lbs 5 oz.
" " the 500 volt armature without shaft 12 lbs 8½ oz.
" " 120 " " " 13 lbs 2 oz.

The spool mentioned on the opposite page was wound with 10 layers of 33 turns each or 330 turns in all of # 25 B.S. 0.017" wire ~~covered~~ cotton covered (double) to 0.027".

Its resistance was 0.92Ω. Its ext: diam: 2.4.

The inductance was 3.4 M.

By calculation the diam: of wire should be

$$\frac{4}{\pi} \times 0.7854 \times 2.25 = 3.412$$

$$d = -0.0127 + \sqrt{1.27 \times 10^{-4} + 0.00154\sqrt{\frac{3.412}{2.92}}} + 0.00154 \times 2.093 + 0.053223 + \frac{161}{0.0033384} + 0.0582$$

$$= 0.0455 \text{ cm}$$
$$= 0.0179"$$

Chart of Thermo Electric Powers of different elements as deduced by Fleming from Matthiessen's experiments.

Six out of the 9 are related in nearly linear order of their atomic weights.

Lead
Mercury
Platinum
Gold
Antimony
Silver
Iron
Zinc
Copper

Millivolts. E.M.F. @ 20°C.

Atomic weights.

Some facts in molecular physics arranged for Comparison.

(125)

The order of contact p.d. in air is taken as the standard.

	Metal	Atomic Weight	Sp. g.	Contact EMF in air	Thermo electric order 0°C	Electro chemical series	Resistivity	Volumetric expansion for 1° C.	Heat Cond.	Melting point	Sp. heat
1	Li.	12.	3·5 (i)	0 (r)		1					
2	Na	23	0·97 (n)								
3	Mg	24	1·7 (d)			15					
4	Al.	27·4	2·7 (bb)			14					
5	Mn	39·1	0·87 (r)			13	288g (w)				
6	Fe	56	8. (g)	0·495 (w)	−17·5 (n)	16					
7	Ni	58·7	9. (oo)			11	9638 (7)	$4·0\times10^{-6}$ (u)	0·1644	1200	0·106 (k)
8	Cu	63·5	8·95 (y)	0·370 (v)	−0·1 (5) −3·8 (m)	10	12,358 (8)				
9	Zn	65·2	6·86 (k)	1·096 (7)	−3·4 (q)	6	·1584 (2)	$5·2\times10^{-6}$ (dd)	1·108	1090	0·090 (v)
10	Ag	108·0	10·5 (nn)			12	5581 (5)		0·307	360	
11	Sn	118·0	7·3 (t)	0·795 (x)	−8·0 (4)	5	1692 (v)	$6·0\times10^{-6}$ (z)		1000	0·056 (w)
12	Pt	197·5	21. (ii)	0·443 (4)	−0·1 (w)	8	13,103 (gg)	$6·2\times10^{-6}$ (k)		2000	0·032 (b)
13	Au	299	19·3 (ff)		−0·9 (4)	3	8982 (4)	$2·7\times10^{-6}$ (i)			0·031 (c)
14	Hg	200	13·57 (aa)		−1·2 (7)	2	28141 (11)	$24·2\times10^{-5}$ (s)		1200	
15	Pb	207	11·3 (o)	0·858 (u)	0·415 (z)	4	934,320 (6)	18×10^{-6} (ll)			
16	Bi	210	9·8 (ee)		0 (ss)	9	19,468 (10)	$8·4\times10^{-6}$ (7)			0·03 (c)
					+97 (t)	7	130,100 (kk)				

One deduction from this table is that the thermo-electric powers are roughly in the order of atomic weights.

The heat conductivities are roughly in the ratio of the electric conductivities.

The specific heats are inversely as the atomic weights (D. & P.'s law).

On the size of wire required to fill a magnet bobbin of the phonograph electromagnetic lift. Res. to be 2·5 ω.

The interflange is 2·25. the int: diam. 1 cm. the ext: 2·5.

The area $(6·25-1)\times0·7854 = 5·25\times0·7854 = 4·1235$

winding space $4·1235\times2·25 = 9·283$.

$t = 0·005 \quad = 5\times10^{-3} \quad t^2 = 2·5\times10^{-5}$

$$d = -\frac{t}{4\pi} \pm \sqrt{\left\{t^2 + 0·0015·4\sqrt{\frac{9·283}{2·5}}\right\}}$$

$$\left\{2·5\times10^{-5} + 0·0015·4\times 6·0\right\}$$

$$0·0092\,25$$
$$0·0000\,25$$
$$0·0092\,00 \qquad = 9·2\times10^{-3}$$

$$\pm 9·7\times10^{-2} = 0·097$$

$$= 0·092 - 0·005$$

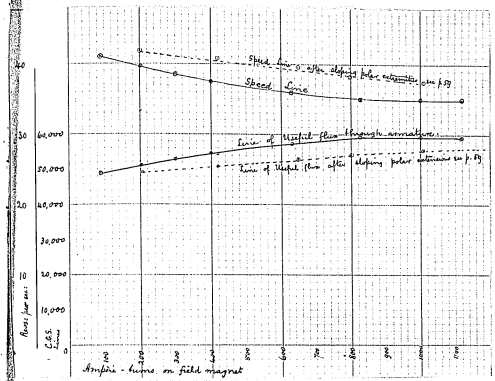
$$= 0·090 \text{ cm.}$$

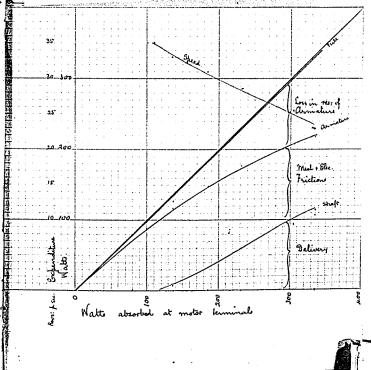
$$= 0·090'' = \#24 \text{ B.S. nearest B.W.G. \#28. silk covered.}$$

Check $d = 0·0392\sqrt{\frac{2·283}{2·5}} = 0·0392\times1·388 = 0·05444$ cm.

No. of Obs.	Lamps in Field ckt	Ohms	Amperes in field ckt	M.M.F. on field.	Field. ° in Arm. ckt	Tangent	Amperes	Volts p.d. on armature	Energy in armature	Drop in arm.
1	1	0.07	0.363	186.8	57°	1.540	1.14	120.75	137.7	17.1
2	2	0.169	0.876	257.7	54°	1.3760	1.018	"	122.9	15.3
3	3	0.245	1.270	373.5	53°.25	1.329	0.991	"	119.7	14.9
4	4	0.320	1.66	488.3	52°.5	1.303	0.964	"	116.4	14.5
5	6	0.52	2.695	792.8	50°.5	1.213	0.898	"	108.4	13.5
6	8	0.68	3.525	1037.	48°.75	1.140	0.844	"	101.9	12.7
7	10	0.825	4.276	1258.	46°.75	"	"	"	"	"
8	12	0.935	4.847	1426.	46°.75	"	"	"	"	"

No. of Obs.	P.D. at motor brs	Ohms	Current thro motor amps	Energy in motor Watts	Drop in field	Amperes in field	Energy in field Watts	Drop in arm.	Energy lost in arm.	E.M.F of arm.	Energy absorbed in effort	Scale Readings
1	120.0	0.220	1.146	137.5	9. Series	993	5.4	17.19	19.7	102.8	117.8	50 to 52.
2	"	0.295	1.537	184.5	"	"	"	23.06	35.4	96.9	148.9	100 to 103
3		0.37	1.928	231.4	"	"	"	28.93	55.78	91.1	177.2	150 to 153 / 200 to 203
4		0.449	2.553	306.3	"	"	"	38.3	97.8	81.7	208.6	250 to 253 / 300 to 303
5		0.55	2.865	343.8	"	"	"	43.0	123.2	77.0	220.6	350 to 353
6		0.535	2.787	334.5	"	"	"	41.8	116.5	78.2	218.0	300 to 15 / 500 to 9
7		.										
4		0.260	1.355	162.6	0.4	317	0.54	20.3	27.5	99.3	134.5	50 to 20
8		0.540	2.813	337.6	0.8	658	2.25	42.2	118.7	77.0	216.6	300 to 15
9		0.160	0.834	100.1	0.3	195	0.25	12.5	10.42	107.2	89.4	0


Speed Line
Speed Line
Line of useful flow through armature
Line of useful flow after slipping pole extensions
Ampère - turns on field magnet



Tests of the small $\frac{1}{5}$ HP (100 Watt) motor.

December 23rd & 24th 1890.

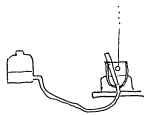
In the first test the field was separately excited. The current in the field was varied and measured, that in the armature corresponding) determined, and the speed also observed. The ratio of angular velocity of armature to indicator wheel (belt driven) was 114.2 Number of turns = 5760 all round.

Emf. applied	Energy lost in res. of arm.	Energy consumed in effort.	Speed: of armature Revs. per min.	Revs. per sec.	Useful flux through the armature	Ampere turns.	Useful flux in driven coil for turns and Amps. not at set	Energy per sec. per sec.
103.6	21.9.6	118.1	2464	41.07	4.62×10^6	85	48,500	2.876
105.5	15.5	107.4	2398	39.7	$4.866 \times$	205	51,100	2.704
105.8	15.8	104.9	2348	38.6	5.022 "	297	52,730	2.719
106.25	14.0	102.4	2244	37.4	5.203 "	389	54.640	2.738
107.25	12.1	96.3	2158	36.0	5.456 "	631	57.300	2.675
108.1	10.6	91.3	2102	35.0	5.653 "	825	59.370	2.608
"	"	"	"	"	" "	1001	"	"
"	"	"	"	"	" "	1134	"	"

The motor was then planted in the bank and tested for efficiency, first with the fields separately excited, and second with the field in series with the armature. Results as follow:—

Moment	Revs. p.m.	Revs. p. sec.	Moment x Revs. p. sec.	Watts delivered at motor pulley	Electrical Eff. of motor	Mech. Eff. of motor	Watts per revs per sec.	Energy absorbed by (gas)	Remarks
410	1986	33.1	1387×10^4	8.378	0.857	0.061	3.106	109.4	110 v 2.8 amp. Driving Library model, 200 Watt S.E. armature light
1675	1860	31.0	5192 .	32.0	0.807	0.173	3.13	116.9	Load 2 x in series
3400	1718	28.6	9724 .	60.0	0.766	0.259	3.21	117.2	- 1 lamp.
6050	1520	25.3	1.531×10^4	94.4	0.681	0.308	3.23	114.2	- 100w
7500	1378	23.0	1725 .	106.4	0.642	0.309	3.35	114.2	- 100w + 1 Lamp in mult
7980	1406	23.4	1860 .	114.7	0.652	0.343	3.34	103.3	- 4 lamps.
1000	2100	35.0	3.5×10^4 .	21.6	0.827	0.133	-	102.9	
7500	1407	23.4	1.755×10^4	108.2	0.642	0.321	-	108.4	- 4 Lamps
0	-	-	-	-	0.89	-		104.2	

When the motor armature was driven light in the unexcited field by the 250 Watt Library model, the speed was 1750 revs. and the moment 900 cm-gm. The energy was therefore 16 Watts. This is the mechanical friction at 1750 revs.



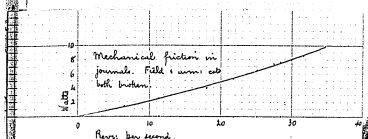
Description of an experiment made 25th Dec. 90, to observe the attraction of solids in water.

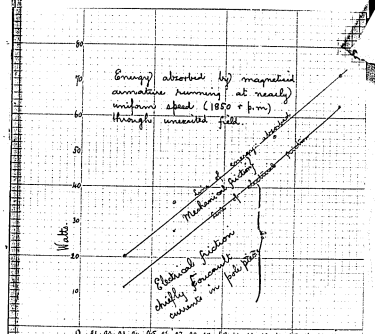
A vertical glass tube about 3.5 cms in diameter, and 10.40 cms long descends from the Ore Milling room on the top floor to a store room in the cellar. Beneath the opening, a glass jar with a stop cock was solidly set. A bottle filled with water was connected to this with a rubber pipe in such a manner that by raising or lowering the bottle, the receptacle could be filled with water or emptied. A sphere of iron 2.5 in diam: was suspended in the receptacle by a german silver ~~cotton~~ 0.09 in diam: single silk cord to 0.020". This wire was fastened at the top of the long tube. A large piece of iron was set in the receptacle so as to almost touch the freely suspended sphere while motionless. The distance between the plate and sphere being about 0.01, and the diameter of the glass receptacle itself being about 15 cms. All being prepared, the water was allowed to slowly enter the vessel, and the results watched for. These were:—

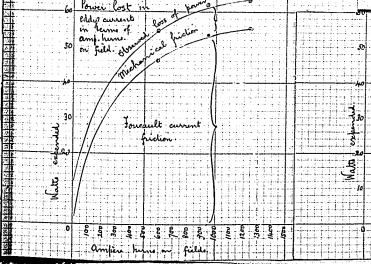
1st The moment the water touched the bottom of the sphere, the latter moved away from the plate. As the level rose, the sphere approached the plate, and finally when covered with water, it rested against the plate enclosing air at the point of contact. On dislodging the air, it was apparent that instead of any attraction between plate and sphere, there was if anything a greater distance between them in water than in air, Several unsuccessful attempts were made to use finer threads of silk or wires to support the sphere, and finally the fall of the sphere broke the glass receptacle.

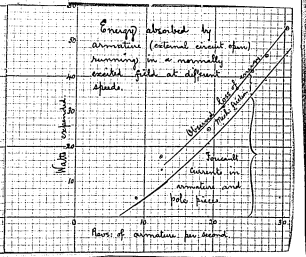
On the friction of a sprocket-chain upon a rubber-covered pulley 30th Dec. 90

The Street-car motor was armed with a 4½ sprocket wheel. The sprocket chain ran over the 24" wheel, faced with rubber, and the tractive power observed by Prony brake reading on the scales. The chain was lightened by an 'idler'. The chain slipped on the rubber when 37.5 lbs was indicated at 8 feet radius = 300 lbs: at 1' rad: 240 lbs: Such chains would slip at 7200 lbs: pull on the chain. The 24" pulley was making 48 revs: per min (equivalent to 4.3 m.p.h. of car) and the energy absorbed by the motor was about 6 amp @ 350v. = 2100 Watts.


Mechanical friction in journals. Field + armt. cct. left broken.
Watts.
Revs. per second.


Energy absorbed by magnetic armature running (at nearly) uniform speed (1850 r.p.m.) through unexcited field.
Watts.
Amperes thro' armature.


Power Lost in
Eddy currents in terms of amp. turns on field.
Mechanical friction
Foucault current friction.
Watts expended.
Ampere turns on field.


Energy absorbed by armature (external circuit open) running in a normally excited field at different speeds.
Foucault currents in armature and pole faces
Watts absorbed
Revs. of armature per second.

Analysis of friction losses in the 100-Watt Model whose test is recorded on page 146.

The motor was fitted with two collector rings over its commutator and brushes resting on them in such a manner that a current could be supplied to the rotating armature at opposite fixed points in the ring. The machine was then floated, and the following measurements made.

1st Test. Pure mechanical friction, armature + field circuits open

No. of Obs.	Revs. of Counter p.m.	Revs. of armature p.m.	Revs. of armature p. sec.	Scale Reading	Moment	Moment × Revs. p. sec.	Watts absorbed in friction	Torque per sq. cm.
1	28	397.6	6.63	5·0 @ 7·2	360	2.387×10^3	1·47	0·232
2	48	681·6	11.36	" 7·2	360	4·090	2·52	"
3	76	1079	18·0	" 7·2	360	6·48	4·0	"
4	92	1306	21·8	" 7·7	385	8·39	5·17	0·237
5	106	1505	25·1	" 8·3	415	10·42	6·42	0·256
6	116	1647	27·5	" 8·7	435	11·96	7·37	0·268
7	120	1704	28·4	" 8·7	435	12·35	7·62	"
8	126	1789	29·8	" 8·7	435	12·96	7·99	"
9	134	1903	31·7	" 9·2	460	13·79	8·50	0·27

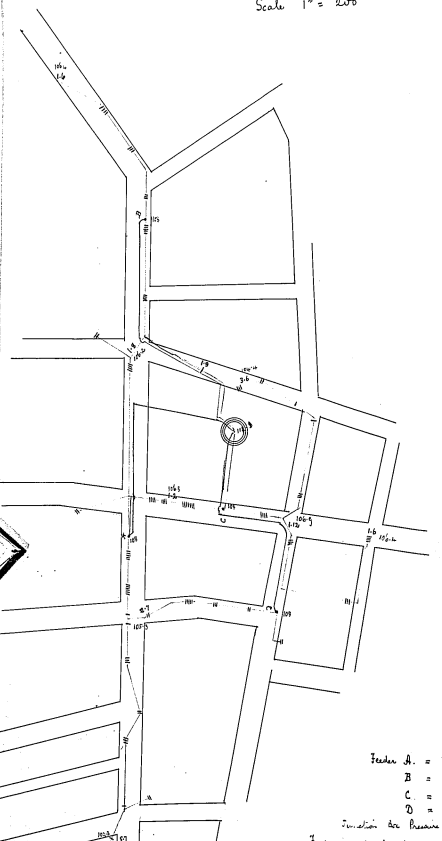
2nd Test. Mechanical friction + effect of a magnetised armature.

No. of Obs.	Revs. of Counter p.m.	Revs. of armature p.m.	Revs. of armature p. sec.	Scale - Readings.	Moment.	Moment × Revs. p. sec.	Watts of power absorbed	Current in armature.	Ratio of electrical to mechanical friction
1	122	1974	31·23	{100 @ 5·; 50 @ 10·9}	1045	3264×10^3	20·13	0·313	12·6
2	130	1846	30·75	{100 @ 15; 50 @ 7·8}	1890	5·812	35·83	0·651	27·5
3	128	1817	30·3	{100 @ 20; 100 @ 10; 50 @ 14·8}	2910	8·818	54·36	1·354	46·2
4	128	1917	30·3	{100 @ 20; 100 @ 12·; 50 @ 7·}	3850	11·670	71·94	1·823	63·7

3rd Test. Mechanical friction + effect of magnetised fields, armature at broken

No. of Obs.	Revs. of Counter p.m.	Revs. of armature p.m.	Revs. of armature p. sec.	Lamps in circ.	Ohms	Current in field	Amperes × Volts in field	Scale	Readings	Moment	Watts absorbed	Ratio elect. mech. friction
1	20	284	4·74	1	0·090	0·469	110	50 @	12·5	625	1·7	0·9
2	40	568	8·8	6	0·480	2·50	585	50 @	27·9	1395	5·4	3·6
3	62	881	14·7	"	"	"	"	{100 @ 50 @	10 17·8}	1890	17·1	13·7
4	78	1107	18·5	"	"	"		{100 @ 50 @	12 13}	2150	25·1	20·7
5	90	1278	21·3	"	"	"		{100 @ 50 @	20 6·9}	2395	31·5	26·3
6	98	1392	23·2	"	"	"		{100 @ 50 @	20 11·3}	2560	36·6	30·7
7	108	1534	25·6	"	"	"		{100 @ 50 @	20 12·1}	2640	41·6	35·1
8	116	1647	27·5	"	"	"		{100 @ 50 @	20 12·3}	2710	46·0	38·9
9	128	1818	30·3	"	"	"		{100 @ 60 @	20 18}	3900	54·2	46·0
10	130	1846	30·8	10	0·7950	4·044	945	{100 @ 50 @	20 25·3}	3265	62·0	53·7
11	128	1818	30·3	"	1·015	5·29	1238	{100 @ 50 @	20 28·2}	3410	63·7	55·5

Part of Trenton N.S. Copied from Directory Map
Scale 1" = 200'



Calculation of Drop in conductors of the Trenton Plant operated on 3-wire or approximately 3-wire system 1886

(49)

There were 1800 lamps operated in 106 different positions on the chart, or about 17.1 lamps at each position on the average. The lamps in 1886 were of 105 volts, and 14.25 N. per candle and if all were of 16 cp = 68 Watts = 0.648 amp each, and 17 lamps = 11.0 amps to each point.

The mains are assumed to have been # 1 B.S. gauge 83,694 c.mils having a resistance of 1.233×10^{-4} ω per foot.

The feeders were assumed to have been #00 B.S. gauge, 133,079 c.mils having a resistance of 7.757×10^{-5} ω per foot, but the feeders were all quadruple, so that their equivalent resistance would be 1.939×10^{-5} ω per foot with a circular mileage of 582.316 equivalent.

There are four principal sections in this system as follows:—

1st A to D: 5 @ 50', 6 @ 150, 1 @ 220, 13 @ 230, 2 @ 300, 5 @ 430, 3 @ 510, 2 @ 600, D - 680 = 106

2nd A to B: 2 @ 120, 4 @ 200, 4 @ 270, 4 @ 290, 4 @ 790, 5 @ 900, 8 930, Sup. off B 10 = 28

3rd A to C: 8 @ 200, 7 @ 300, C 400 = 15

4th C to D: 4 @ 120, 10 @ 180, 2 @ 250, 3 @ 320, 7 @ 330, Sup. off D 2 = 26

The C.G. of these parts are 2.80, 2.80', 5.30, 5.30', —, —, 2.40, 2.40'

and the increments are 220 @ 320 from A, 12 @ 460 = 220 D; 8 @ 320 from A, 10 @ 760 = 770 from B; 8 @ 200 from A, 7 @ 100 - C; 14 @ 165 from C, 1 @ 340 = 120 - D

The circuit A to X: 1 @ 15, 3 @ 120, 2 @ 280, 3 @ 370, 1 @ 580, 3 @ 610, C.G. = 13 @ 310

D offset: 3 @ 200, 4 @ 400, 7 @ 310

B offset: 3 @ 270, 3 @ 320, 4 @ 360, 10 @ 220

C offset: 3 @ 20, 1 @ 300, 1 @ 380, 2 @ 500, 3 @ 570, 10 @ 360

Off Feeder A: 25 on AD @ 220, 8 " AB @ 320, 8 - AC @ 200, = 41

B: Offset 10 @ 10 on BB @ 170 = 20

C: 7 on AC @ 300, 14 - CD @ 165 = 21

D: 12 on AD @ 220, 10 - D @ 120, 2 - offset @ 100 = 24

The drop on A = $20.5 \times 700 \times .81 \times 1.939 \times 10^{-5}$ = $2.05 \times 7.0 \times 1.1 \times 1.939 \times 10^{-1}$ = 3.06 volts

B = $10 \times 770 \times 11 \times 1.939 \times 10^{-5}$ = $1 \times 7.7 \times 1.1 \times 1.939 \times 10^{-1}$ = 1.64

C = $10.5 \times 220 \times 11 \times 1.939 \times 10^{-5}$ = $1.05 \times 2.2 \times 1.1 \times 1.939 \times 10^{-1}$ = 0.493

D = $12 \times 670 \times 11 \times 1.939 \times 10^{-5}$ = $1.2 \times 6.7 \times 1.1 \times 1.939 \times 10^{-1}$ = 1.72

The drop on AD = ~~12.5×320~~ $4.000 \times 1.233 \times 10^{-4} \times 5.5$ = $4 \times 5.5 \times 1.233 \times 10^{-1}$ = 2.71

AD X = $13 \times 3.40 \times 5.5 \times 1.233 \times 10^{-4}$ = $1.3 \times 3.4 \times 5.5 \times 1.233 \times 10^{-1}$ = 3.0. Total 5.7

AB = $2.600 \times 1.233 \times 10^{-4} \times 5.5$ = $2.6 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.76

B offset = $2.310 \times 1.233 \times 10^{-4} \times 5.5$ = $2.31 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.56

Station offset = $.200 \times 1.233 \times 10^{-4} \times 5.5$ = $2.0 \times 1.233 \times 5.5 \times 10^{-5}$ = 0.114 2.4

AC = $1.800 \times 1.233 \times 10^{-4} \times 5.5$ = $1.8 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.22

CD = $1.650 \times 1.233 \times 10^{-4} \times 5.5$ = $1.65 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.12

C offset = $3.660 \times 1.233 \times 10^{-4} \times 5.5$ = $3.66 \times 1.233 \times 5.5 \times 10^{-4}$ = 2.48

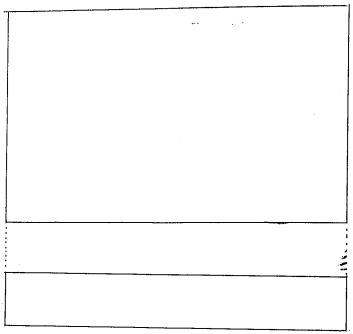
D offset = $2.200 \times 1.233 \times 10^{-4} \times 5.5$ = $2.2 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.49

2.7
5.7
1.76
1.56
1.9
1.2
1.1
3.6
1.6

The drop on the mains varies from 1.1 to 5.7 . Mean drop on 9 lowest points 2.16

" " " feeders " 3.6 to 2.5 Mean drop - 4 feeders 2.73

Plan and Side Elevation of boat (External dimensions)
Scale 1" = 1 foot.



(As actually) constructed, the outer tank is 167 × 106 × 36·5 internally
The inner tank is 153·5 × 91 × 26·4 externally } Weight 115lbs = 68·5 kg.
148·5 × 86·5 × 22·4 internally }
14000 sq. cms. of outer base.

On the dimensions of a tank to float 400 lb motors. (52)

400 lbs = 181440 gms = 181,440 c.c. of water say 200,000. With an immersion of 15" cms. this gives an area of 13,330 sq. cms. With a breadth of 3' (41·5) = 124·5 cms. = 5'7¼ = 4'·9½". Say 3'×5'×6" immersion + 9" free board. 10" ext. depth.

Calculation of the length and size of wire needed on the magnets of the small Edison 100-Watt motor.

The diameter of the core is 1.25", and the length between flanges 3.6". The mean diam. may be taken as 1.75", and the mean circum. = 0.458'. If the current needed to drive the motor light, be taken as 0.50 amp. and 300 amp turns be adopted for the light magnetisation, see the curve on p. 46, then 600 turns will be needed, and the length of wire = 300' approx. The maximum current will be 2·5 amperes, and the fall of potential should not exceed 2·5 volts = 1 v., then 1 v of # 18 B.W.G. should be used = 1·7 lbs. say 1 lb. 12 oz. 233' = 500 turns. s.c. wire 0·046" to 0·057" so that there will be 60 turns per layer and 8 layers or 0·48" deep.

Data of Edison Gravity Voltmeter

This instrument is described in Record Book (smaller) # 3 pag + 81. It consists of a balance scale beam having a solenoid on one arm that is attracted by a similar larger fixed, and coaxial solenoid on the base. The two solenoids are in series. Before the instrument was sent to the Paris Exhibition, the range was 5 volts and 0·28 gms on each side for a current of 0·75 amperes. On its return to the Laboratory from the Minneapolis Exhibition the main knife edge was found broken and after repair and shortening, the range was greater and the instrument not so sensitive. The fixed solenoid was then changed. It consisted of 396 turns (6 layers of 66 turns each) of # 18 B.W.G. wire 0·049" silkcovered to 0·057". The brass shell had an ext. diam. of 1·82, weighed empty 117 gms, and had an inteflange of 10·3. This winding was changed for four layers of 225 turns (900 in all) of platinoid wire 0·011" covered to 0·0175". This winding was found to have too much resistance and (1200 ω) and was again changed for 772 turns 8 layer of 96·5 turns of 0·020" wire s.c.c. to 0·036". Int. diam. 2·3" Ext. diam. 3·9" Res. 1535 · 0·14 Ω.

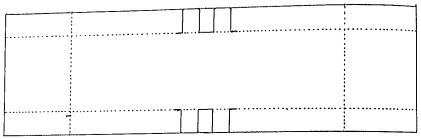
The inner solenoid consists of 4 layers of 65 turns (260 turns in all) of 0·014" d. silk c. to 0·058". The diameter over wire is 3·06, the internal diameter of the shell 1·82, and the winding diameter (external of shell) 2·05. Length of solenoid shell 10·5, interflange 9·75. Weight of solenoid shell (rubber) and casing 260 gms.

With the last winding, the pull was 0·225 gms with a current of $\frac{103}{270}$ = 0·436 amps, and at 220·5 degrees, but the sensitiveness to variation of current was not sufficient.

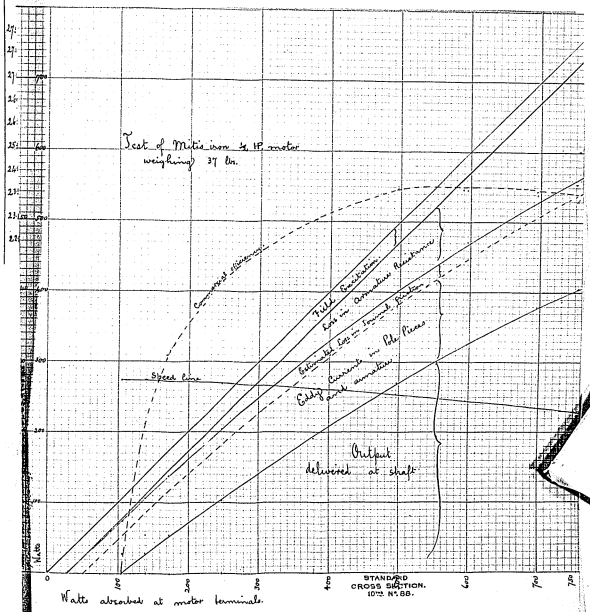
A new knife edge was then made for the instrument to increase the distance between the centre of inertia and the point of suspension. When this altered, a current of $\frac{103}{140}$ = 0·779 amps exerts a pull of 0·63 gms and a variation of pressure from 106 to 112 was nearly sufficient to carry the instrument over the whole scale.

Res. of interior solenoid and connecting wire 0·55 Ω

Instrument sent to Mr Edgar, Boston, for trial 16th Jan-91.



No. of Obs.	P.D. at motor terminals	Current through motor	Current through armature	Energy in Watts	Energy in field winds	Energy in armature	Calculated drop in armature	Em.f generated by armature	Energy lost in armature	Energy exerted in mech. effect	Revs. of armature p.m.	Rel. ener
1	121	0·233	–	28·2	25·2	–	–					
2	"	0·860	0·627	104·1	"	75·9	0·25	118·2	34·8	74·1	1650	
3	"	1·146	0·913	138·7	"	110·5	0·140	117·0	30·9	106·8	1625	
4	"	1·433	1·200	173·4	"	145·2	0·53	115·7	6·3	138·9	1625	
5	"	2·032	1·799	246·0	"	217·8	0·79	113·1	14·3	203·5	1615	
6	"	3·126	2·893	378·3	"	350·1	1·27	109·3	36·8	313·3	1575	
7	"	4·090	3·857	494·9	"	466·7	1·70	104·0	65·6	401·1	1530	
8	"	4·923	4·690	595·7	"	567·5	2·06	100·4	96·6	470·9	1470	
9	"	5·756	5·523	696·5	"	669·3	2·43	97·7	128·8	534·5	1410	
10	"	6·082	5·809	731·2	"	702·9	27·9	92·1	162·1	540·8	1380	
11	"	6·251	6·018	756·4	"	728·2	28·9	92·1	174·0	554·2	1370	
				4333·1		4333·1						


Test of Mitis iron ¼ HP motor
weighing 37 lbs.
Commercial efficiency
Field Excitation
Loss in Armature Resistance
Friction Hysteresis Eddy Currents in Pole Pieces
Eddy Currents in Armature
Output delivered at shaft
Speed Line
Watts absorbed at motor terminals.
STANDARD CROSS SECTION. 10 TO No. 28.

Test of Mitis Iron 3/4 H.P. Motor 27th Dec. 90.

This motor has an armature whose data are given on page 147 both III. The field magnet and pole pieces are of mitis iron. The weight of the machine on a wooden base 11" × 11" is 37 lbs, and its actual extreme dimensions are 9" × 10" × 11". The armature has 42 grooves each 0.21" wide and 0.325" deep holding 50 turns 10 layers of 5 turns each of #23 BWG. 0.025" S.W.G. The cross section of iron in the ring is 6.75 sq cm (2.5 × 2.7) The diameter of the commutator is 1.43" (42 segments of mica insulation) The brushes are blocks of copper gauze, resting nearly vertical, and cover nearly 3 bars. The core has a diameter of 1.875" and the interflange length is 3.8". The diameter over wire is 2.875". The resistance of the armature coil (including platinoid) is 11.4Ω, hot 14.8Ω. The inductance of the armature with 2 or 3 amps of current is 0.180 H (180 ms). The resistance of the field coil is 520Ω, the inductance 42.6 H.

The motor was floated, and coupled to the 1000 Watt Edison dynamo

E.M.F. (Armature terminals)	Scale Gms	Scale Reading	Moment	Moment/ω	Driving watts	Input-Output Friction watts	Mechanical Efficiency	Armature Electrical Efficiency	Magnetic Data	
	–	–					–			Field only (1)
	–	–				74.1	–	0.976	$\phi = 2.2 \times 10^6$	Running light (2)
	50 @ 4.8 100 @ 15		1740	1.073×10^7	29.12	77.12	0.212	0.967	$\phi = 1.1 \times 10^6$	Driving Armature light (3)
	50 @ 4.35 100 @ 10 100 @ 28		3225	1.988	53.9	85.0	0.241	0.957	$\phi = 1.6300$	Driving Armature & Mica ring & coil (4)
	50 @ 23 500 @ 10		6150	3.792	102.0	101.5	0.434	0.934	in the above	Lamp (5)
	50 @ 23 100 @ 10 (100 @ 23)		11,750	7.244	190.6	122.7	0.644	0.895	occupied by paper and tin	3 . (6)
	50 @ 23 100 @ 10 (500 @ 10) (1000 @ 23)		17,200	10.66	270.3	130.8	0.546	0.859		5 . (7)
	50 @ 23 100 @ 15 500 @ 10 (1000 @ 10)		21,550	13.29	325.6	144.9	0.546	0.830		7 . (8)
	50 @ 23 100 @ 15 500 @ 15 (1000 @ 15)		26,100	16.09	378.2	161.3	0.543	0.807		9 . (9)
	50 @ 23 100 @ 15 500 @ 23 (1000 @ 15)		27,250	16.80	386.4	154.4	0.529	0.769		11 . (10)
	50 @ 23 100 @ 15 500 @ 23 1000 @ 15		28,800	17.76	405.0	144.2	0.535	0.761		12 . (11)

Further considerations and Data connected with the proposed Street-Car motor improved Sprague type represented on page 36.

In The data received from the Engineering Dept: on the 18th Dec were as follow:- Armature Drum. 14" core diam: face 12.5"
Commutator 72 divs.
Estimated speed 800 r.p.m. (necessary to reduce to 300)
Armature winding 900 cmils per amp:
Field bore 15½":
Clearance over all ⅛".
Field core 4" × 8½" wide × 15" long.

The data received on the 31st Dec. were :—
Armature Drum 14" core diam: face 13".
Area of field core 51 sq: in:
length " " 15"
Area of polar surface 460 sq: in:
Speed 300 to 800 r.p.m.

With the new data, allowing 54 sq: in: of cross section in the field core = 329 sq. cmils. With 18,000 lines per sq. cm this represents 5,922,000 lines. Allowing 33% leakage gives 3,968,000 lines usefully employed, say 4×10^6 as an extreme limit.

To develop 500 volts the no: of wires all round must be
$5{\cdot}0 \times 10^{10} / 4 \times 10^6 \times 5 = 5{\cdot}0/2{\cdot}0 \times 10^3 = 2{,}500$ or 1250 drum turns.

The field bore being 15½" the winding external diam: is 15".
The core being 14", allowing for insulation and binding, the winding depth is 0.4". The mean diam = 14.4" a circum: of 45.24" and a winding area of 18.1 sq in:
This space occupied by 2500 wires will give 18.1/2500 = 0.0072 sq: in: per wire. = 0.085" diam: = 0.09" bare wire = 5,625 cm. mils and allowing 900 c.mils. per amp: = 6.00 amperes
The output of the machine at 100% efficiency would therefore be 12 × 500 = 6 Kilowatts.

The #6 Edison standard dynamo, has a core 8.25" in diam. = 53.45 sq: in. It generates 125 volts @ 1500 revs. with 192 wire on its armature (96 turns). The diam: of wire is 0.180 bare or 32,400 c.mils. and this wire carries $\frac{6 \times 20}{2}$ = 60 amperes, or an area of 540 c.mil. per ampere. If it generated 500 volts at the same speed, and with the same winding space, the covered diameter would be 0.095 ÷ 2 say 0.0975 or a bare diameter of 0.088". If then it had to generate 500 volts at 300 revolutions, the diameter of covered wire would be reduced ⅘ or 2.23 times 0.0144" covered = 0.034" bare = 1156 c.mils = 2.14 amp. The machine will now generate 4.28 × 500 = 2140 Watts while its original power was 15000 Watts.

Resumé

Quadripolar Gramme Ring Dynamo

4000 Watts

80 volts 50 amperes

500 revs: per min.

Limiting temp: elevation 50°F.

Armature Thin sheet iron.

External diam:	over bindings:	23.750
	over wire	23.125
"	over body mic:	22.925
"	over core	22.825"
Internal "	under core	18.55"
"	wire	18.35 a 18.20

Breadth over core 6.75

over wire. 7.0 a 7.2

Cross section of core 149 sq.in. = 93 sq cms

Commutator divs: 240

Winding 720 turns of # 12 B+S.

Diam: of bare wire 0.081"

" cond: wire 0.095"

Circular mils 6561

Res: mils per amp: at full load 486

Length of armature wire 1150'

Weight " " 23 lbs

Field: Cast Mitis iron. Bore 23.34

Diam: of cores: 4.5"

Cross section of cores 15.9 sq in.

Area of pole surfaces 71.5 sq in.

Contefer: 0.268"

Winding: #19 B+S.

Diam: of bare wire 0.036"

" " cond: wire 0.0444" S.C.C.

Length " wire on each shoe 13,360'

Weight " " " " 552.4 lbs. 240 in all

Resistance " " " 107 ω.

External diameter of wound coil over wire 8.3"

over insp. 8.5"

Current in field at full load. 3 amps

Energy expended " " 240 Watts.

Fall of pot: in arm: 7 volts.

Energy expended " 371 watts

Electrical loss of energy in field + arm: 611 Watts. independent of eddy currents.

Revised Calculations for a 4 Kilowatt Machine to be constructed by the Engineering Department

See p. 20

The breadth of the armature is 17, the depth 5.5, the cross section 93.5 sq cms. Allowing only 0.8 of this for available for iron gives 74.8 sq cms.: With a density in iron of 10,000 this gives a useful flux of 750,000, and the polar flux = 1.5×10^6. The e.m.f. to be developed is $90 \times 10^8 = 9.0 \times 10^9$ and the revs. p.s. are $\frac{500}{60} = 8.33$. Hence the no: of wires all round will be $9.0 \times 10^9 / 8333 \times 1.5 \times 10^7$ or 720. Say 800. The diam: of the armature internally is 18.25" corresponding to a circ: of 57.3" and the breadth per wire is 0.0716", allowing 0.014", this becomes 0.058" # 17 B.W.G. 3364 c.mils = 2.50 c.mils per amp. The length of one turn on the armature will be 19" = 1.6'. The total length of wire on the armature will be 1280' and the res: = $1.280 \times 3.069 \times \frac{1}{16} = 0.245$ cool or 0.3 ω hot. This means a drop of 15 volts at full load.

If 720 wires be taken the breadth for each wire is 0.0796". Allowing 0.015" = 0.065" = # 16 B.W.G. the resistance in this case would be $720 \times 1.6 \times 2.44 \times 1/16 \times 10^{-3} = 0.177$" = 0.2 ω hot and a drop of 10 volts at full load. The c.m.s = $\frac{142.25}{1845} = 313$.

If now the cut: diam: only be considered 22.9" = 71.94" circ: of which 10% may be considered unavailable, leaving 64.75". There with 760 wires, the breadth per wire = 0.085", and allowing 0.013" for insulation gives 0.072" # 15 B.W.G. 5184 c.mils = 3814 c.mils per amp. res: per foot = $2 \times 10^{-3} \times 760 \times \frac{1.6}{16} = 0.152$ ω cool or 0.17 ω hot, and the drop at full load = 9 volts.

With 720 wires, the diam: of the covered wire = 0.095" and allowing for insulation 0.015" = 0.081" # 8 B.S. = 6.84 " required cut of 22.9 + 0.1 = 23 × 3.14 = 72.25" = 6561 c.mils, or 1486 c.mils per amp. The res: = $6.58 \times 720 \times \frac{1.6}{16} \times 10^{-3} = 0.114$ ω cool = 0.13 ω hot = 7 volts drop at full load.

The useful flux being $1.5 \times 10^{8} \times 1.6$ for $r = 2.44 \times 10^4$, and 4" cores give 81 sq/ cms. $B = 2.44 \times 10^4 / 2 \times 81 = 1.5 \times 10^4$

Allowing 4.5" = 15.9 × 6.45 = 102.6 and a density of 12,000 The mean turn on the core will be 1.5' approx.

The polar surface is $26 \times 17 = 442$ sq. cms and the contefer = 0.1 + 0.125 + 0.1 = 0.325" = 0.82 cms. The reluctances then to each cores circuit in air = $\frac{0.64}{521} = 0.0074$ lucts. The reluctances of the armature is $33 \times 0.0015/50 = 0.0006$. The reluctances of the core is $56 \times 0.002/80 = 0.002$. Total reluctances 0.01 in each cores circuit. The flux needed being 750,000 the M.M.F. called for is 7,500, and the amp: turns = 6000. Allowing for armature effect, say 7000 amp: turns. The surfaces of each coil is 800 sq: cms. and allowing 25 sq/ cms. per watt = 160 Watts. = 0.75 amp: = 9,300 turns. The resistance hot of the coil must be 107 ω and 9300 turns = 14,000' = 131' per ω = # 19 B.W.G. = 0.19 lbs: per ω. = 524 lbs. per cm. 0.036" covered to 0.0444" = The spaces occupied will be 29 c.in. = 36.4 sq/in. = 4.6 to 8.3". The length will be 13,360' and the mean diam: 6.45" = 20.3" circ: = 1.7' = 7,850 turns. 180 turns per layer, and 44 layers. = 1.9" deep.

If wound for 20 volts on each core, the current = 3 amperes and the resistance 6.67 ω hot = 6 ω cold. the number of turns needed = 2300 and the length 3910' = 652' per ω. # 12 B.W.G. 0.072" cond: 6.0.050" 47.2 lbs. on each core. 500' per ω = 3000'

Also to determine under these conditions the space through which the impact drives the compresses the body

We have $v = V\cos(t\sqrt{\mu})$

$ds = V\cos(t\sqrt{\mu})\,dt$

$\therefore s = V\frac{\sin(t\sqrt{\mu})}{\sqrt{\mu}}$

when $t = \tau$ the space is a maximum

$s = \frac{V}{\sqrt{\mu}}$

$= V\tau\sqrt{\frac{\rho}{\eta}}$ or $V\sqrt{\frac{m l}{\eta a}}$

For the steel cube of unit edge length considered

$s = 2V \times 10^{-6}$

On the Mathematical Laws connecting the periods of free impact in simple masses, with their elastic moduli

Let AB be a perfectly rigid and unyielding barrier.

" C . . body in the form of a rectangular parallelepiped, moving with a velocity V in free space.

" m be the mass of C

" a be the area of the impinging face

" l . . length . . body

" s . . distance moved over by the body dating from the least instant of impact

" t " the time dating from the instant of impact.

" v " " velocity . . . . .

" η " Youngs Modulus for the material of the body C.

Then the fundamental law regulating the motion is

$$m\frac{dv}{dt} = -f = -\eta\frac{as}{l}$$

$$\frac{dv}{dt} = -\frac{\eta}{m}\frac{a}{l}s = \mu s \quad \text{say}$$

$$\frac{d^2v}{dt^2} = -\mu v$$

The solution of which is $v = \alpha\sin(t\sqrt{\mu} + \beta)$

when $t = 0$ $v = V$ $\therefore V = \alpha\sin\beta$

$\therefore \beta = \sin^{-1}\frac{V}{\alpha}$

Also $\frac{dv}{dt} = \alpha\sqrt{\mu}\cos(t\sqrt{\mu}+\beta)$

and when $t = 0$ $\frac{dv}{dt} = a$ $\therefore 0 = \alpha\sqrt{\mu}\cos\beta$

$\therefore \beta = \frac{\pi}{2}$ $\therefore V = \alpha$

$\therefore v = V\sin(t\sqrt{\mu} + \frac{\pi}{2})$

$= V\cos(t\sqrt{\mu})$

Hence for $v = 0$ $= 0$

$t\sqrt{\mu} = \frac{\pi}{2}$

or $t = \frac{\pi}{2}\sqrt{\frac{m_{\rho}l}{\eta a}} = \frac{\pi l}{2}\sqrt{\frac{\rho}{\eta}}$

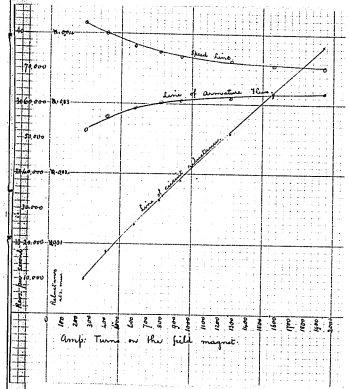
From which we deduce that the time of contact varies as the square root of the density directly, and the square root of the material Young's modulus inversely. Also if the body C were to oscillate between two such barriers without back lash, or loss of energy, its velocity would be a simple harmonic function of the time.

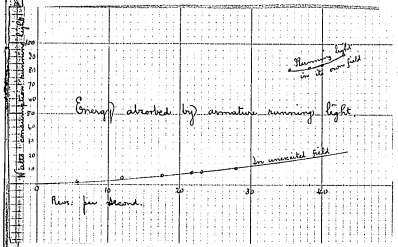
For a steel cube one cm. in length of edge, impinging against a rigid barrier the time of contact would be, assuming no loss of energy

$$\tau = \frac{\pi}{10^6}\sqrt{\frac{8}{3\cdot7}} = \frac{6}{10^6} \text{ second}$$

The time of contact should also be independent of the velocity.

In Book I. at pages 85-87 are recorded the results of some measurements made with spheres of different metals impinging upon a steel faced anvil. With spheres 2·5 in diam. the time was found to be practically independent of the velocity. Also the time of contact for such spheres was found to be with steel, copper, and zinc, to be 9·8, 11·1, and 10·3 $\times 10^{-5}$ respectively. $\sqrt{\frac{\rho}{\eta}}$ for these metals are $\sqrt{\frac{8}{2\cdot7\times10^6}}$, $\sqrt{\frac{8\cdot9}{1\cdot23\times10^6}}$, & $\sqrt{\frac{7}{?}}$ that is 1·938 : 2·695 :: 9·8 : 12·25, and this is for steel against infinite rigidity and copper against infinite rigidity, instead of steel against steel, and copper against steel.


Stark time
Loss of armature Power
Loss of energy by Hysteresis
Amps: Turns on the field magnet.


Energy absorbed by armature running light.
Running light
Run: per Second.

Tests of 1/8 H.P. motor after fitting with laminated polepieces 85

The pole pieces are 2.5 wide radially, increasing to 2.8 near the extremities. They taper in thickness from 1.1 to 0.6, and they are each formed of 8 pieces, welded together in the centre.

The weight of the motor and ~~adapt~~ wooden base (pulley included) is 23 lbs.

The resistance of the field (cool) is 0.97Ω, it consists of 9 layers of 514 turns each (4586 turns in all) of #18 S.W.G. 0.048" d.c.c. to 0.065".

The inductance of the field is 83.24 with the armature in place.

The inductance of the armature in unexcited field is 4126

The resistance of the armature coil averages 14.68Ω. The brushes cover two bars of the commutator, and are of soft copper strips.

The following series of observations was made with varying excitation of the field coils. The motor running light. 122.5 lbs

1903

No. of Obs.	Current in Field Ampere	Ampere turns	MMF Ats.	Flux thro armt	Reluctance of circuit	Speed of armt R.P.M.	Current in armt	Energy supplied to motor	Energy per watt
1	28°45' 3.975	1932	2439	63,400	3.83×10^{-2}	2122	35.44	0.667	81.7	2.31
2	23°35' 3.230	1570	1974	63,180	3.12	2130	35.5	-	-	2.3
3	19°30' 2.620	1273	1600	61,980	2.58	2170	36.2	-	-	2.26
4	14°30' 1.91	928	1167	60,950	1.915	2210	36.8	-	-	2.22
5	12°15' 1.666	780	981	60,130	1.632	2238	37.3	-	-	2.19
6	9°20' 1.238	602	757	58,720	1.290	2293	38.2	0.677	82.9	2.17
7	6°20' 0.821	399	502	56,080	0.895	2402	40.0	0.693	84.9	2.12
8	3°25' 0.431	210	264	52,170	0.586	2580	43.0	0.755	92.5	2.15
	0.155									

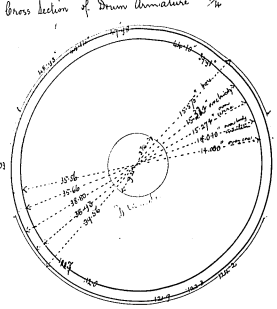
In calculating the flux through the armature, the no: of wire is taken at 586

The friction was then determined under various conditions

No. of Obs.	Revolutions per min	Revolutions per sec.	Scale	Reading	Moment	Watts Nominal	Energy absorbed	Energy per Revolution	Energy per min.	Energy per sec.
									owing to brush fric	due to axle fric
1	344	5.7.3	50Ω	9.3	465	2.567×10^4	1643	0.287		
2	622	10.04		10.7	535	3,299	3.310	0.33		
3	800	13.33		11.2	560	3,453	4.160	0.345		
4	1045	17.4		12.9	595	3,668	6.38	0.367		
5	1300	21.7		12.3	615	3,793	8.23	0.379		
6	1380	23.0		12.8	640	3,946	9.08	0.395		
7	1670	27.8		13.8	690	4,255	11.83	0.426		

This last test was made with the brushes down but the field unexcited.

Cross section of Drum Armature 1/4



Power 25 H.P. = 18,650 Watts @ 500 volts @ 85% eff. 43.9 amp.
Speed Minimum at full power 800 revs. per min = 13.33 per sec.
Dimensions
Drum armature Wright iron plates. Bore diam: 14.0" 35.56
Body Dia. 14.04" 35.66
Breadth of core 13". Over wire 15.274" 38.80
Effective for magnetic conduction 10.6". Over binding 15.324 38.93

Field Wrought and mitis cast Iron.
Length of core 15". Breadth 13". Thickness 4"
Cross section 50 sq. in. = 322.5 sq. cms.

Armature Winding. 136 Sections, 136 Commutator blocks.
2720' of #20 B.W.G. 0.134" cond. D.C.C. 0.152". 819 cms. per amp.
4 layers of 2 turns each in each section. 17.956 cms.
544 complete turns.
Weight 150 lbs. circa
Resistance between brushes 0.040 ohm.
Drop at full load in arm: 17.5 volts
Energy expended resistantly . 768 Watts
Film loss: 136 of 0.015" each.

Field winding. (a) Multiple (b) Series. Mean turn 3.75'.
4 equal spools on each core 3.5" X 13.5". Or copper ½" thick:
Free surface 6000 sq. cms. Surface per watt. 15 sq. cms. per W.in
(a) No. of each spool 12.500. 2 in series (one on each core) 2800 " "
Current in each spool 0.2 amperes.
58 Yds. of #28 B.W.G. 0.020" cond. to 0.028" in 108 layers of 120 turns each
1980 turns in all = 408.1480' = 124.50 m. Depth of winding 3.5".
(b) No. of each coil 62.750 (coils) . 78 " = 30.2 lbs.
of #20 B.W.G. 0.035" cond. to 0.043". Current in each spool 0.8 amp
27 layers of 75 turns = 2025 turns or 7690' of wire on each spool.
Depth of winding 1.5" on copper ⅛" thick.
Current in the field 0.8 amp. to 0.8
Energy expended . . 480 . . 400 Watts.

Magnetic circuit. Bore 14,000 lines per sq.cm = 5.16 X 10^8 lines
Armature at full saturation 0.7 = 3.61 X 10^8 ℓ about 5,000
Reluctance of core 0.0025
Interpolar 0.0020
armature 0.0001
Total 0.0046 X (18,620 X 1.1 X 1.257) = 3.96 X 10^8

Torque = 1088 X 13.9 X 10^8 X 3.61 X 10^8 ÷ 6.28 dynes = 2.746 X 10^9 = 2.80 X 10^6 gms.
= 2800 kgms. at 1 cm. rad. = 2760 lbs. @ 1 cm = 205 lbs. at a rad. of 1 ft
If the minimum speed of the car be 50 r.p.m. of car(s)/wheel. the power = 269. lbs. at the car axle.

Copy of Determination sent to the Engineer-in-Chief.

Data of Electromagnetic Motor, for a 25 H.P. Street Car motor
1,000 lbs. at 400 revs. and minimum speed of 100 revolutions per minute.
Current, allowing 85% efficiency, 44.0 amperes at full load.
Armature core. Armature core diameter 14.0"
over body insulation 14.04"
Over wires 15.274"
Over binding wires 15.324"
Breadth of armature core 13" (or 12.76" any)
Iron armature core of wrought iron plates in present Sprague type.
Field magnet of Mitis iron, yoke of wrought iron.
Bore breadth 13", Thickness 4".
Cross section nearly square. 50 sq. in.
Armature winding 136 sections, 136 commutator blocks.
2720' of ⅛ 10 B.W.G. wire 0.134", covered to 0.152"
given 17,956 c.mills, or 819 c.mills. per amp. at full load.
136 fiber divisions or armature edges 0.015" each.
544 complete turns round armature making 8 wires,
(four layers of two turns each) in each section.
Weight of wire on armature about 150 lbs.
Resistance of armature between brushes, 0.040 ohm hot.
Drop in armature at full load 17.5 volts.
Energy expended resistantly in armature at full load 768 watts.
Field winding (a) multiple series. (b) Simple series.
(a) Four equal spools on each core.
Current in each spool 0.2 amperes.
58 Yds. of ⅛ B.W.G. 0.020" cond. 120 to 0.028" on each spool
No. of each spool 12.50 ohms. 2500 feet. 12,500 turns
100 layers of 120 turns each .
Depth of winding 3.5" including cordage.
(b) 4 equal spools on each core. 30 lbs. of ⅛ B.W.G.
0.035" cond. to 0.043" on each spool 240 lbs. in all.
27 layers of 75 turns on each spool 2050 turns or 7690'
Depth of winding 1.5" including cordage. Spools 1/4" thick (copper)
Resistance of each spool 78 ohms hot.
Energy in field at maximum current 0.8 amp. 400 watts.
Torque of motor 205 lbs. on armature shaft at rad. of 1'

Determination of the Winding for a 25 HP Street Car Motor, already alluded to on pages 38 + 82, to be made for the Engineering Department.

The entrefer in the Sprague #6 street car motor is given in Parshall's paper on the subject as 1.6 cm (25.4 − 22.2 / 2). The entrefer in the proposed dynamo might be increased 25% on this or to 2.0 cms. This is 0.787", so that retaining the armature diameter as 11¼", the bore of the field will be 15.575".

Of the entrefer, allow

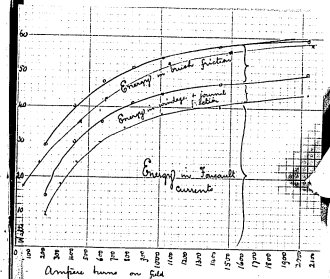
clearance over all	0.125"
binding wire	0.028
body insulation	0.020
Winding depth	±0.613"
	0.787"

With a cross section of 50 sq. in. in the core and mitis-iron, it would be possible to obtain 16,000 lines per sq. cm. and a total induction of 5.16×10^4 lines through the core, of which 60% will be useful, 3.1×10^4 lines will pass through the armature. Then 500 r.p.m. @ 500 volts = 13.33 r.p.s. and $w = 5 \times 10^8 / 13.33 \times 3.1 \times 10^4 = 1.21 \times 10^3$. Perhaps 70% might be expected in which case $p = 361 \times 10^3$ in which case $w = 1039$ say 1050. The mean diameter will be 4.638" mean circ. = 14.598" and the depth 0.617" = 28.38 sq. in. of winding space. $28.38 / 1050 = 0.02703$ sq. in. = 0.164" cond. diameter allowing no lost spaces. It will be actually necessary to use 11 layers each 0.154" cond. and allowing 0.015" for insulation gives 0.139" bare = #10 B.W.G. 0.1314", 17,956 cm. which with 25 HP = 19,650 Watts @ 85% eff = 21,940 Watts = 21.94 amps. in the wire = 819 cms. per amp. On the winding circle 11 + 0.02 + 0.03 = 11.15" diam = 44.38" circ. There will be room for 292 wire each 0.152" bare 280. There will then be 1120 wire in all 11 layers with fibre partitions 0.015" thick, and 128 commutator blocks there will be 10 wire in 128 sections two wide and four deep. The breadth of each section = 0.319" and 128 of these make 43.38". There will thus be $136 \times 11 = 574$ turns on the armature. The length of each turn will be about 5' so that the resistance of all the wire will be 1.553 the res. between brushes, 0.388, the length of wire $574 \times 5 = 2720'$, the weight 146.6 lbs.

The poles area is $17.5 \times 12" = 210$ sq. in. = 13.54 sq. cms. The reluctance of the air space is therefore $4/13.54 = 0.00296$ lucts. The length of iron circuit is 62" in the field = 157.5 cms of 322 sq. cms. x section = $157.5/322 = 0.49 \times 0.005 = 0.00245$ lucts. The reluctance of the armature is $35 \div 0.80 \times (32 \times 25) = 35/640 \times 4 = 0.0547 \times 0.002 = 0.001$ luct. The total reluctance will thus be 0.0065 lucts. The MMF for 3.6×10^4 is $23.4 \times 10^3 = 18,620$ AT. add 10% for arm. effect. = 20,500 AT.

The surfaces of the coils is $37 \times 128 = 4735$ sq. cms. This does not include the interior surfaces facing each other. Allowing 15 sq. cms. per Watt the available energy is 316 Watts say 400 allowing including interior faces. This gives 100 Watts per pair of quarter coils or 50 Watts per spool. The current will then be 0.2 amps. for each pair = 2500 ω or 1250 ω per spool. The A.T. per spool = 2560 = 12,800 turns. The mean perimeter is 402" = 33.5' so that the length = 444.800', the length per ω = 35.84 = #20 B.W.G. The weight per ω = 0.047 lbs. = 58.7 lbs. = 470 lbs. in all. The space occupied by this winding will be 2610 c.i. Single cotton covered, the bare diam. = 0.020" covered 0.028". Wound 0.03. The winding breadth = 11/8 = 3.5 so that there will be 116 turns per layer. There will be $38.75 \times 1250 = 43,480'$ = 13,280 turns of 3.65' = 1115 layers = 3.43" deep = 3.5" on paper.

If wound in one series, the current = 0.5 amps, the total res. 625 ω = 480 ω cond. = 68.75 ω per spool. the turns = $2560 \times 0.8 = 1610 \times 8 = 2050 = 7004 = 11,800$ ft. = #20 B.W.G. 0.035" cond. to 0.043". = 2/3 of 75 turns per layer = 27 layers = 1.20" = 1.5 cm.


Energy in Friction
Energy in Eddy + Friction
Energy in Transmitted Current
Ampère turns on field

Calculation of a Series winding for the ½ H.P. motor as applied to 220 or 550 volts.

There are 1600 A.T needed on the ½ H.P. field to practically saturate it. 600 AT would however be permissable, for light load. Supposing that it take 50 Watts to run the motor light, then @ 240 volts the light current will be 0.21 amp. and consequently 2000 turns will be required. 600 Watts being the maximum intake = 2.5 amps @ 240 volts the maximum drop allowed may be 10 volts. = 4% res: The mean diam: being 2.5" the mean circ: = 8" = 0.67' and 2000 turns = 2000 × 0.67 = 1340' per ω = #13 wire say = 4 × 7.9 = 31 lbs. With 2500 turns, the length is 1670' and with 12.5 volts drop at full load of 2.5 amp. = 5 ω. = .3334' per ω. = #17 B.W.G. = 5 × 3.33 = 16.5 lbs.. With 2000 turns = 1333' = 15 volts drop at full load = 6 ω = 222' per ω. = #18 B.W.G. and 6 ω = 10 lbs. With 1500 turns = 1000' and 6 ω = 166' per ω = #19 B.W.G. and 6 ω = 5.44 lbs. This will occupy 30 cubic ins., or 10 sq: ins: per " of minimum length (3") = 4.0" externally.

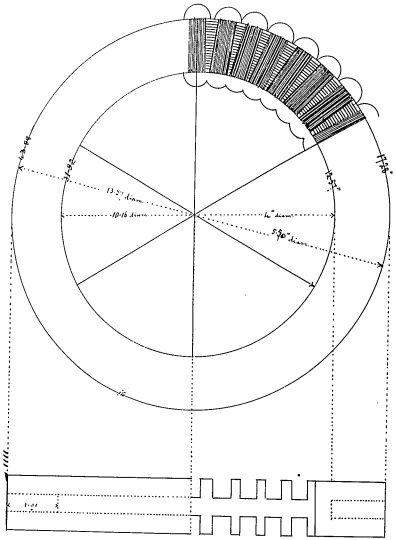
Tests of ½ H. P. Motor with laminated pole pieces.

The motor was balanced in the boat and was driven by the Mite ½ H.P. motor. The energy absorbed in overcoming mechanical and electrical friction was measured as follows:—

No. of Obs.	Speed of armature Revs. per sec.	Current in the Brush amperes	Current in the field: Amp. turns	Moment of Reaction Dynes-cm.	Energy Watts	Moment of Reaction Grammes cm	Energy Watts	Energy in windage & friction	Energy in brush friction + energy in eddy currents	Energy in eddy current
1	27.8	0.0		899	14.5	375	6.3	6.3	20.8	0
2		0.081	0.422	205	1710	28.9	935	15.8	6.3	13.1	9.5
3		0.158	0.823	400	2365	40.	1770	29.9	6.3	10.1	13.5
4	Mean 27.4	0.245	1.276	620	2780	47.0	2110	35.8	6.3	11.3	18.1
5		0.322	1.678	815	3010	51.	2435	41.1	6.3	9.9	24.9
6		0.400	2.084	1013	3210	54.2	2590	43.8	6.3	10.4	27.1
7		0.565	2.944	1431	3395	57.35	2745	46.4	6.3	10.95	29.1
8	27.0	0.810	4.220	2051	3490	59.0	2935	49.6	6.3	9.4	33.9

By comparing these results with those recorded on page 48 taken with the same motor having solid pole pieces at 30 r.p.s. see, it appears that the lamination of the poles has reduced the light load eddy current loss about 12 Watts or 25% at normal field excitation. This effect would probably be still greater for loads.

The greatest fault now existing in the motor was its noise, the passage of the teeth under the polar extremities, laminated as these were gave rise to a strong rattle or whir. To obviate this, it was decided to alter the shape of the pole pieces, so that instead of terminating radially they were cut off at an angle of 66° with the vertical. This had the desired effect. The rattle was reduced to an amount that could be tolerated.



PARTICULARS OF EDISON MODEL 1/16 HORSE POWER MOTOR.

Weight on wooden base with pulley 14 lbs. 2 oz.
" fan 15 lbs.

Winding gramme-ring and series field.
Voltage 120 at machine terminals.
Amperes at delivery of 1/16th. HP. 1.4 amp.
Running light with resistance in circuit 0.38 amp.
Commercial efficiency at delivery of 1/16th. HP. 30%
Speed running light 4400 revs. per min. , but with resistance inserted. 2520 r.p.m.
Speed at delivery of 1/16th. HP. 2200 r.p.m.
Dimensions:-
Armature body , diameter external 5.5", internal 4.0"
Number of grooves 42 on each side.
Breadth of armature body over teeth 0.27"
at base of grooves 0.25"
Depth of grooves 0.26" , breadth 0.24"
Band iron in core 0.01" thick, wound in short lengths.
Cross section of armature core 1.2 sq. cms.
Breadth of teeth 0.21" at external, 0.06" at internal circle.
Insulation 0.003" mica at sides, 0.008" oiled silk on base.
Polar surface of teeth 12 sq. cms. under each pole.
Winding , 98 turns viz. 11 layers of 9 turns each of #28 BWG. wire covered to 0.024".
Commutator divisions 42.
Total length of wire on armature nearly 880 feet.
Total weight " " " "0.6 lb.
Resistance of armature between brushes including German silver connections 14.0 ohms cool and 15.4 ohms hot.
Current in armature at full load 1.4 amperes.
Drop in armature at full load 21.6 volts.
Energy expended in heating armature wire at full load 30 watts.
Magnetic flux through armature section 15,000 C. G. S. lines.
Induction density in core space , (paper and iron) 12,500
Field magnet of Mitis cast wrought iron.
Pole pieces solid, and of wrought iron.
Core diameter 0.918" Inner flange 3.6"
Diameter over wire 2."
Flux through core center at full load. 60,000
Flux through core center at full load 15,500
Induction density of core at full load
Winding about 3000 turns of wire # 24 BWG. 0.022" covered to 0.031". [illegible] with covered wire cord, for want of proper size covered
Resistance of field winding 25.5 ohms cool, and 28 ohms hot.
Energy in field at full load 39 volts. Energy 55 watts.
Drop in field at full load
Resistance coil of german silver wire to reduce speed of motor on light load, wound over field magnet wire, 150 ohms of # 28 BWG wire about 125 feet.
Total resistance of motor between terminals 190 ohms cool and 195 ohms hot including resistance.
Brushes of copper gauze to cover two blocks of commutator.
Connections from armature to commutator g.s. 0.0005"5.1 ohms

On the Electromagnetic Design of a 1/16 H.P. Motor (50 Volts)

to be constructed on the same general plan as that of the larger type, but with resistances in the circuit to reduce the pressure on the armature to 60 volts. The armature to be also reduced in diameter.

In the 1/8 H.P. motor there are 5,460 turns on the armature, the flux is 60,000 nearly. The speed 2100. The intake at full load 300 Watts.
Supposing the maximum intake on the new motor reduced to one-third 200 Watts, of which 50 Watts had to be delivered by the shaft.

Allowing 12,500 lines per sq. cm. of core cross section (paper and iron) the area must be 30,000 ÷ 12,500 = 2·4 sq. cm. = 1·2 sq. cm. on each side.
The depth being 1·905". the width must be 0·63 cm. = 0·248" say 0·25".
The same number and width of grooves as in the 1/8 H.P. model.
Big 42 grooves each [0.016" deep and 0.010" wide]. Total Breadth 25/32 = 0·777".
Top of ridge [0·052"] Heat of ridge [0·020"]

Speed with 60 volts on the armature, running light 36·6 revs. p.s or 2196 revs. per min. Perhaps 3500 when light.

The area of one side of the armature is 72·2 sq. cm. of which 56 lie in the grooves leaving 16·2 for the teeth = 0·386 sq. cm. for each tooth. Of such teeth are always under each pole surfaces on each side, or 82 in all = 12·34 sq. cms. of surface constituting each pole. ℓ in the teeth = 2,730. The reluctance of the air gaps is

$$\frac{2 \times 0.05}{12.34} = 0.013$$

$\frac{g}{2}$ cms. of iron: 1·2 sq. cm. @ 15,000 $\frac{46.5 \times 0.092}{1.2} = 0.0075$

Reluctance of armature. 0.0205

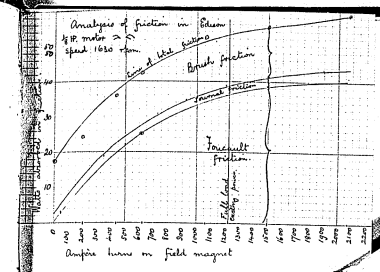
The resistance of the armature if wound with the same wire as that on the 1/8 H.P. viz 0·0155" s.c.c. to 0·0285", or even if it be wound with 0·014" wire (# 28 B.W.G.) would be 0·022". The res. of the armature will be about 1½ ω. The energy wasted in the armature will be say 50 Watts.

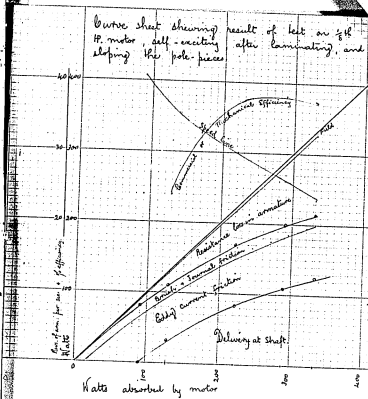
The cross-section of one of the mitis iron legs is to be 0·3 sq. in. The breadth is 0·5". the width 0·75". it is required to find the radius of curvature which allowed to smooth off the edges will bring the section to the right amount. This will be when

$$\pi r^2 + (0.5 - 2r)2r + (0.75 - 2r)0.5 = 0.3$$
$$3.145r^2 + r - 4r^2 + 0.375 - r = 0.3$$
$$-0.86\,r^2 = -0.075$$
$$r^2 = 0.0872$$
$$r = 0.295"$$

Weight of the iron armature core & spider 620 gms.
Thickness of the iron band 0·01".
The experimental winding of the 1/16 H.P. field was 14 layers of 66 turns each # 19 B.W.G. = 924 turns.
Weight of completion 15 lbs.
The armature was wound with 11 layers of 9 turns (99 turns in all) in each groove as the covering of the wire was too thick to allow of more than this. Total wire all round = 4158

No. of Obs.	P.D. on motor	Current in motor (Brush)	Ampère	Energy in motor	Current in field Ampère	Ampère turns on field	Energy in field Brush	Energy in field Ferranti	Energy in armature	Calculated drop in armature	E.M.F. generated by armature	Speed of armature Rev. per min	Frictional loss Watts
1	122·25	0·120	0·625	76·5	1·73	864·1	1·7	2·0	76·5	9·37	112·8	2280	38·9
2	"	0·195	1·015	124·2	"	"	"	"	124·2	15·2	107·	2085	34·75
3		0·342	1·781	218·1	"	"	"	"	218·1	26·7	95·5	1812	30·2
4		0·460	2·396	293·4	"	"	"	"	293·4	36·0	86·3	1610	26·8
5		0·540	2·813	344·5	"	"	"	"	344·5	42·1	80·2	1415	23·6
6	122·25	0·141	0·734	89·9	0·734	357	1·73	0·58	89·4	11·0	110·6	2150	40·8
7		0·200	1·042	127·6	1·042	507	1·82	1·08	126·5	15·6	108·7	2120	35·6
8		0·348	1·813	222·1	1·813	881	1·81	3·28	218·9	27·2	93·3	1800	30·0
9		0·458	2·396	287·1	2·396	1139	2·34	5·46	281·6	35·2	87·6	1565	26·19
10		0·522	2·719	333	2·719	1321	2·72	7·40	325·6	40·8	78·8	1410	23·50


Analysis of friction in Edison ½ H.P. motor at 1650 r.p.m.
Curve of total friction
Brush friction
Armature friction
Ferranti friction
Field friction in Watts
Ampère turns on field magnet



Tests of the ½ H.P. Motor after tapering off the pole pieces. 8th Jan. 31.

First test, for determining the natures, and degrees of friction. Motor balanced in boat, and run by the Mitis non ½ H.P. motor.

No. of obs.	Speed of Motor r.p.m.	r.p.sec.	Current in Field Brush	Amps	Field Amp. turns	Scale Reading 50 grms	Reading Moment	Energy absorbed	Conditions	Frictional energy	Total friction
	1620	27.16	0	-	-	3·2	160	2·68	Brushes off	-	17·7
	-	-	0·082	0·427	207	11·2	560	9·4	-	6·7	24·6
	-	-	0·175	0·911	443	25·2	1260	21·1	-	18·4	35·8
	-	-	0·248	1·290	627	32·9	1645	27·6	-	24·9	42·3
	-	-	0·333	1·735	843	50·3	2515		-		
	-	-	0·42	2·187	1063	44·8	2240	37·5	-	34·8	52·7
	-	-	0·592	3·083	1498	48·7	2435	40·8	-	39·1	58·5
	-	-	0·820	4·270	2075	51·9	2595	43·5	-	40·8	58·7
	-	-	0	-	-	20·8	1040	17·4	Brushes down	-	17·4
	-	-	0·820	4·270	2075	69·3	3465	58·0	-	40·6	98·0

For the plotted curve of these results see p. 57, as well as opposite.

Second Test for efficiency. The ½ H.P. motor, driving the mitis ¼ H.P. as dynamo.

No. of obs.	Scale Reading grams	Moment	Moment ÷ 2·165	Watts delivered by shaft	Effort	Effort — Diff. (friction)	Mechanical Efficiency	Electrical efficiency.		
97	-	-	-	-	70·5	70·5	-	0·922		
105	[50 @ 7·2 / 100 @ 10]	1110	$6·842 \times 10^6$	23·8	108·6	84·5	0·192	0·875		
116	[150 @ 10 / 100 @ 15 / 100 @ 12]	4000	$2·467 \times 10^7$	74·5	170·1	95·6	0·342	0·780		
122	[200 @ 20 / 100 @ 25]	6500	$4·009 \times 10^7$	107·5	206·7	99·2	0·347	0·705		
40	[150 @ 20 / 100 @ 25 / 200 @ 25]	8820	$5·451 \times 10^7$	128·7	235·6	96·9	0·281	0·655		
71	-	-	-	-	81·2	81·2	-	0·903		
7	500 @ 20 / 200 @ 25	1400	$8·63 \times 10^6$	20·7	180·1	79·4	0·261	0·863		
4	1000 @ 20 / 1000 @ 25	45000	$2·775 \times 10^8$	433·25	169·2	86·	0·375	0·762		
4	1000, 1000 @ 10, 1000 @ 20	6800	$4·193 \times 10^7$	107·4	198·3	88·9	0·381	0·691		
15	1000, 1000 @ 10, 1000 @ 15, 1000 @ 20	8550	$5·272 \times 10^7$	123·9	214·3	90·4	0·372	0·644		

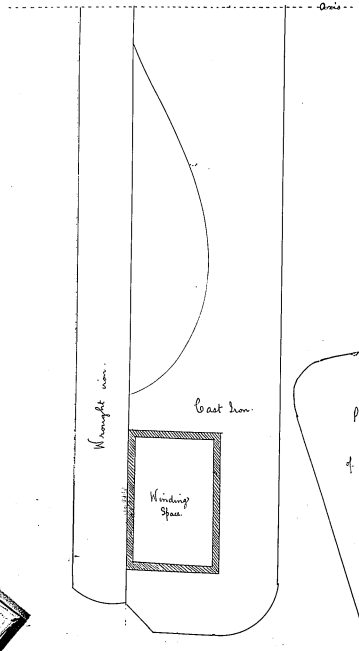
The exciting power necessary to saturate the armature was then determined as follows — Separate excitation.

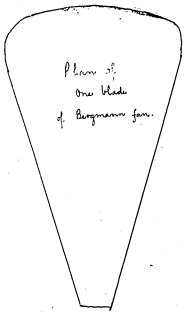
No. of obs.	P.D. on Motor	Brush	Current thro motor	Drop in armt.	Emf generated by motor	Ring transmt	Amps	Amp. turns	Speed of armature R.p.m.	R.p.sec.	Calculated Flux
1	122·5	0·140	0·729	10·9	111·6	-	0·427	207·5	2516	41·9	48,780
2		0·130	0·677	10·2	112·3	0·1154	0·854	414·5	2448	40·8	50,430
3		0·115	0·599	9·0	113·5	0·1804	1·339	651	2380	39·7	52,350
4		0·120	0·625	9·4	113·1	0·2217	1·642	798	2299	38·3	54,080
5		0·110	0·573	8·6	113·9	0·2851?	2·112	1027	2244	37·4	55,800
6		0·105	0·547	8·2	114·3	0·3895	2·773	1834	2163	36·0	58,150

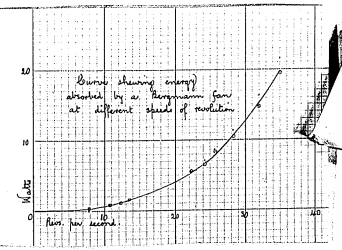
For the plot of these results see the dotted lines on the curve sheet of p. 46. (opposite.)

The result of stepping away the pole pieces has therefore been to increase the effort for the same excitation about 5% or reduce the armature flux about 5%, to greatly reduce the noise of the motor's operation, and to slightly reduce the frictional losses (about 3 Watts) and the brush sparking. Altogether a marked improvement.

Cross Section of Electromagnetic clutch taken through the axis. Full size.







Calculation for the dimensions of a clutch to transmit the power of the Edison #2 street Car Motor direct on the same axle.

The Edison # 2 D.C. Motor has to exert 22·5 kwts: at full load = 16,600 ft lbs: per second: ; and the speed being 14 revs: per sec: = 4,150 ft lbs. per rev. the radius = (feet) the pull is $\frac{4150}{2\pi r}$ lbs. weight = 660·5 This pull is divided between two clutches, so that the moment of each is 330 ft × lbs wt. The clutch described at page 126 Book III had a moment of 1300 ft × lbs wt. with 4·3 amperes. The clutch to be designed must operate effectually at 5 amperes and not overheat at 50. Each clutch must not exceed 0·125 ω resistance.

Taking the mean radii of action as 8·3" and 5·75" = circ. of 52·1 and 36·1" inches. Each 0·5" hood = 26 sq: inches of surface or 26 sq: in: acting at a rad: of 8·3" and 18 sq: in: acting at a radius of 5·75. Assuming $\mathfrak{L}$ = 16,000 $\mathfrak{L}\pi = 2.5\pi \times 10^4 + \frac{\mathfrak{L}\pi}{4\pi} = 10^7 = 10000$ = 22 lbs: per sq: cm: = 140 lbs. per sq: in : Allowing say 100 lbs. per sq: in : the moment expected will be 2600 × 0·7 + 1800 × 0·48 = 2684 ft × lbs: wt. With $\mathfrak{L}$ = 8,000 (cast iron) we should still have 900 ft × lbs. weight

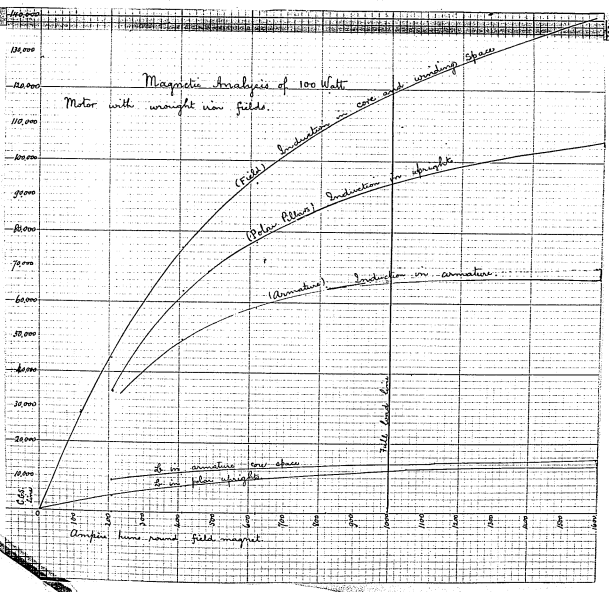
The mean radius of the winding = 7", and the cross section is 1·8 sq: in: The total volume is thus 44 × 1·8 = 79·2 sq: cubic in = 14·4 lbs. This must have a res: of 0·12 ω or 0·00833 ω per lb. # 9 B&S Diam. 0·1148 = 0·160" covered dia. Layer of 11 turns = 66 turns = 247·5', The ampere turns at light load will be 330, the mmF 410. With 0·05 cms air space, the reluctance per sq: cm: would be 0·05, and the flux 82,000.

Test of the power taken in revolving a Baumann fan at different speeds. 10th Jan., 91.

This fan has four blades at right angle. They planes make an angle of 25° with the plane normal to the axis, except one which makes about 31°. They are made of sheet brass 0·032" thick. The tip to tip diam = 23, and the greatest breadth is 6·45. The outline is represented on the opposite page. The ⅛ H.P. motor was floated, and the fan was driven by a flexible coupling to the fan armature shaft. The brushes of the fan motor were lifted, and the fields left unexcited.

Trial No.	Speed of Counter r.p.m.	Speed of fan r.p.m.	Speed of motor r.p.s.	Balance 50 @		Moment	6165 × Moment	Electrical Energy Watts	Remarks & Speed Ratio	Electric proportion
	20	408	6·8	torque	8·2	60	370 × 10⁶	0·25		
	47·5	646	10·8	-	2·3	115	7·09	6·77		
	54	734	12·2	-	2·7	135	8·32	1·02		
	59·5	809	13·5	-	3·5	175	1·079 × 10⁷	1·46		
	98	1333	22·2	-	8·0	400	2·467	5·48	Uniform	Uniform
	107	1455	24·25	-	8·9	445	2·743	6·65	1·0925	7·16
	114	1550	25·8	-	10·3	515	3·175	8·2	1·162	8·60
	125	1700	28·3	-	11·8	590	3·638	10·3	1·275	11·96
	141	1918	31·97	-	15·0	750	4·624	14·77	1·24	16·37
	155	2108	35·1	-	18·05	903	5·567	19·54	1·581	21·66
	155	2108	35·1	-	27	1350	8·324	29·2	Board held in front of fan causing the flow of air.	

The work done by the fan varies approximately as the cube of the speed.

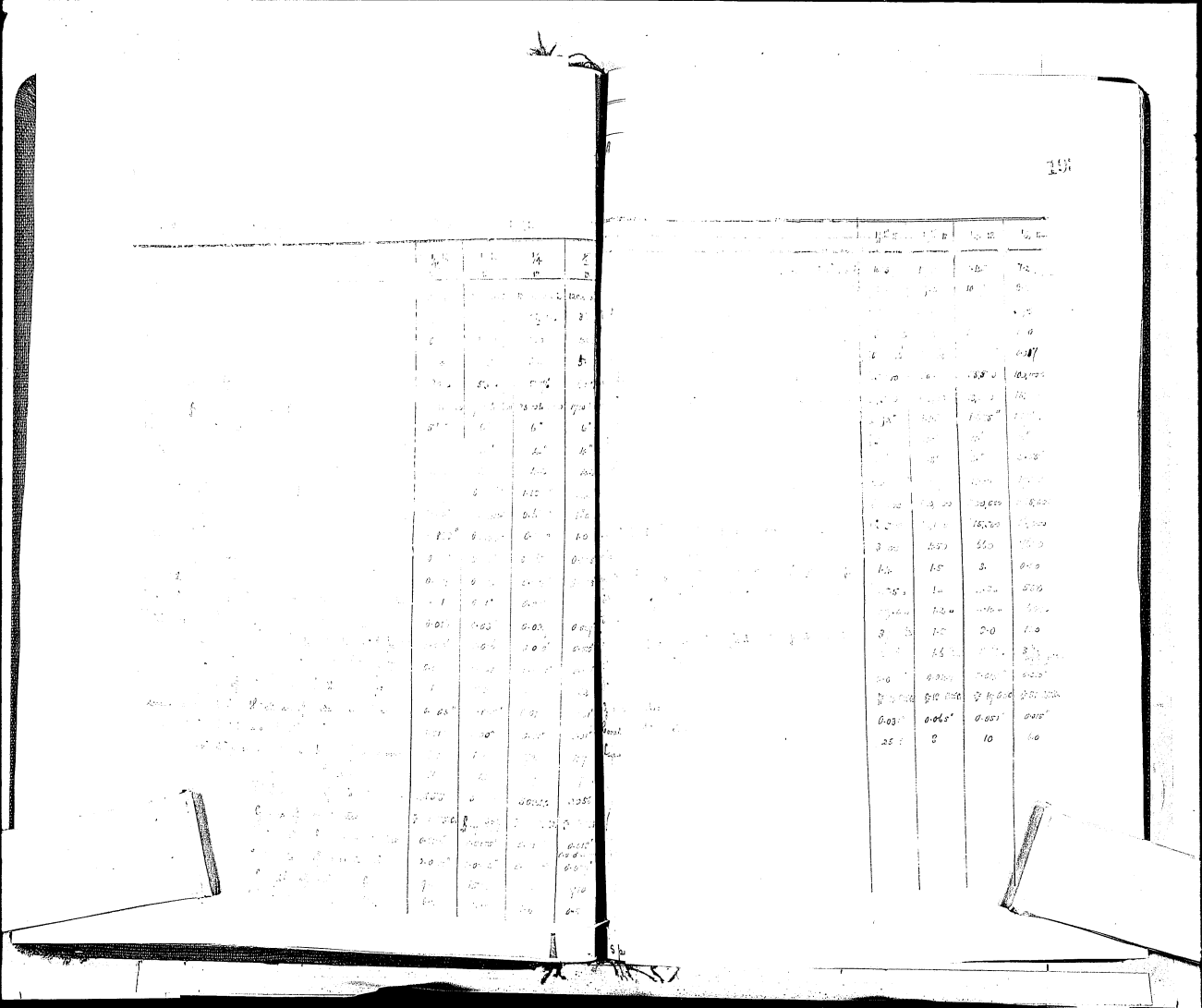

Magnetic Analysis of 100 Watt
Motor with wrought iron fields.
(Field) Induction in core and in working space
(Pole Pieces) Induction in shunts
(Armature) Induction in armature
B in armature core shoes
B in pole shoes
Field Lines per sq. cm.
Ampere turns round field magnet.

Magnetic tests of ½ H.P. Motor after stepping polar extremities 9th January 1891.

Five turns of insulated wire were wound upon (1) the field magnet centre (2) the four upright legs (3) the armature above and below midway between the poles, and the extremities taken to the ballistic galvo.

No. of Reading	Sample in Table of	Obsvd.	Current	Amp. turns	MMF	Mean Pond × 10	ℛ	ϕ	B	Dimensions and Q.
1		0·081	0·422	205	257·6	67	8·38×10⁷	44,000	5,580	Iron 1·25" diam: = 7·89 □
2		0·162	0·8444	410	515·3	115	14·39 -	75,560	9,580	
3		0·245	1·276	620	779·2	143	17·9 -	93,960	11,910	
4		0·325	1·693	823	1034	166·8	20·84 -	109,500	13,880	
8		0·65	3·385	1645	2067	212	26·52 -	139,200	17,640	
1		0·081	0·422	205	257·6	27·5	3·442×10⁷	18,060	4,588	2·52 Bundles K 1·55 = 3·907 Left hand Top side
2		0·162	0·8444	410	515·3	49	6·13 -	32,180	8,174	
3		0·245	1·276	620	779·2	59	7·38 -	38,750	9,8444	
4		0·325	1·693	823	1034	67	8·38 -	44,000	11,180	
8		0·65	3·385	1645	2067	78·5	9·82 -	51,500	13,080	
1		0·081	0·422	205	257·6	24	3·00 -	15,750	4,000	Left hand Top side
2		0·162	0·8444	410	515·3	43	5·38 -	28,240	7,174	
3		0·245	1·276	620	779·2	56	7·01 -	36,800	9,348	
4		0·325	1·693	823	1034	63	7·88 -	41,380	10,510	
8		0·650	3·385	1645	2067	77·5	9·70 -	50,920	12,940	
1		0·081	0·422	205	257·6	28	3·50 -	18,370	4,666	Right hand Top side 24 Bundles
2		0·162	0·8444	410	515·3	52	6·50 -	34,130	8,670	
3		0·245	1·276	620	779·2	62	7·76 -	40,740	10,350	
4		0·325	1·693	823	1034	69·5	8·70 -	45,670	11,600	
8		0·650	3·385	1645	2067	82	10·26 -	53,860	13,680	
1		0·081	0·422	205	257·6	27	3·38 -	17,750	4,510	Left hand Third Leg
2		0·162	0·8444	410	515·3	47	5·88 -	30,870	7,842	
3		0·245	1·276	620	779·2	60	7·51 -	39,420	12,010	
4		0·325	1·693	823	1034	67	8·38 -	44,000	11,180	
8		0·650	3·385	1645	2067	82·	10·26 -	53,870	13,690	
1		0·081	0·422	205	257·6	31	3·88 -	20,370	5,174	Armature Left hand Top Section 2·18 Diam.
2		0·162	0·8444	410	515·3	37	4·63 -	24,310	6,174	
3		0·245	1·276	620	779·2	44·5	5·56 -	29,190	7,420	
4		0·325	1·693	823	1034	46	5·75 -	30,190	7,670	
8		0·650	3·385	1645	2067	51	6·38 -	33,490	8,510	
1		0·081	0·422	205	257·6	25	3·13 -	16,430	4,174	Armature Left hand Bottom Section 2·18 Diam.
2		0·162	0·8444	410	515·3	37·5	4·69 -	24,620	6,254	
3		0·205	1·276	620	779·2	44	5·50 -	28,870	7,334	
4		0·325	1·693	823	1034	46	5·76 -	30,240	7,680	
8		0·650	3·385	1645	2067	50·5	6·32 -	33,180	8,430	

No.	Source of E.M.F.	E.M.F.	Capacity	Q.	Mean Throw	Q. per unit deflection
	1 D.C. @ 20°·0	1·4325	2	2·865×10⁻⁷	229	1·251 ×10⁻³



Resumé of Dimensions of Small Model Motors.

Dimension	⅛ HP 5·0 watts	¼ HP 100 watts	½ HP 200 watts	¾ HP 400 watts	1 HP 800 watts	1½ HP 1200 watts
Armature: Ext. diameter	5·5" 139·7	6" 152·4	6" 152·4	6" 152·4	7" 177·8	6"
Int: "	4" 101·6	4" 101·6	4" 101·6	4" 101·6	4·5" 114·3	4"
No. of grooves	42	42	42	42	42	42
Extreme breadth	077"	0·406" 2·30	1·182"	1·45"		1·65"
Core breadth	0·25"	0·344" 0·87	0·662" 1·68	1" 2·54	1·25" 3·16	1" 2·54
Depth of groove:	026 0·66	028 0·715	026 0·66	0·225" 0·57	1·50" 10·0	0·225" 0·57
Breadth "	0·24" 6·6	021" 0·61	0·24 0·61	0·225" 0·57	0·375	0·26
Weight - armature core	6 lbs.			6 lbs.		
Polar surface on teeth	12·8 cm	20·8 cm	20·8 cm	32·8 cm	42·8	26·8 cm.
Number of turns per groove	99 4/158	130	92	49	30	90
Layers.	11	13	9	7	6	9
Diam: of conductor	0·0114"	0·0155" 0·394	0·019"	0·018"	0·022"	0·014"
Covered diam:	0·0224"	0·0225" 0·572	0·0285"	0·029"	0·030"	0·023
Body insulation	0·01"	0·003" 0·020	0·010	0·01"	0·01	0·01"
Thickness of iron core slip	0·1"	0·029" 0·074	0·029"	0·029"		0·01"?
Commutator divs:	42	42	42	42	42	42
Length of wire on armt	980'	1500'	1008'	910'	845'	1860'
Weight - - - -	0·6 lbs.	1·15 lbs	0·99	0·94 lbs	2·5 lbs	1·1 lbs
Res: of armt: between brushes	14·2·5 15·4	16·0 w 17·72 19·4	8·0 9·45 9·2 10·4	8·2 w 9·2 10·2	1·85 1·8 2·	22·5 22·2
Resist: on armt: at full load (hot)	1·43	1·89	3·33	4·5 amp.	11·1	2·73
Drop - - - - -	21·6 w	26·6	307·8	37·5 volts	20 v.	60 v.
Energy - - - - -	30·2	40	102. 120	170 watts	222	162
Flux thro armature (full load)	15, 000	30,000	53,500	100,000	150,000	100,000
mean B in core apex.	12,500	13,760	13,000	15,000	15,000	15,000
Diameter of core. Width	.5875" 14·9 mm	1·25" 3·175	1·6" 4·064	1·875" 4·76	2·5" 6·35	2" 5·08
Depth	0·218" 5·53	0·44" 11·18	1·675" 4·255	2·47 6·27		
Interflanges.	3·6 9·2	4 10·2	4" 10·2	4"		3·8"
Diameter of wound core	2" 5·1	2·28 5·8	3·0" 7·72	2·5"		3·25"
Area of core. Width	3·87	1327 7·89	4·05 12·9	2·75"	4·91 31·7	3·14" 20·2
Depth	4·26	6·90 9·30	11·2		5·61 35·25	
Flux. (full load)	60,000	120000	200,000	285,000	750,000	320,000
B in core. (full load)	15,500	12,120	15,500	16,000	16,000	4,000
No: of turns on field	3090	450	660	7630		806
Current thro' field (full load)	1·47	1·54	3·37	0·284 0·290		2·71
Amp. Turns (full load)	4200	675	2240	1,700 1,830		2176
M.M.F. (full load)	5280	849	2,650	2,130 1,910		2736
Energy in field	55 w.	2·8 w.	26 w.	2·7·4		27·0
Res: of field (full load)	25·45 27·90	1·2 w 1·3 w	2·3 2·5 w	550 w 600 w		3·5 3·70
Drop in field (full load)	29·1	1·8 v.	8·8 v.	120 volts		10 v.
Weight of wire	1·6 lbs.	1·62 lbs	2 lbs	3lbs 1·7 kgs		3·1 lbs
Bare diameter wire	0·022"	0·049"	0·062"	0·01"		0·032" 0·800
Covered - -	0·031"	0·065"	0·058"	0·015"		0·051"
Layers.		8	10	60?		13
Speed of armature R.p.m.	4000 & 2200	2500 & 2000	2,500 & 1,200	1750 & 1300	1700 & 1300	3000 & 1200
R.p.s.	73·3 36·7	41·3 33·3	41·7 20·3	29·2 21·7	28·3 21·7	50 - 20

Electromagnetic Design for a ½ HP (200 Watt) Edison motor for 120 volts 3.3 amp. 11th Jan.

Power 200 Watts at full load. delivered by shaft
100 - lost - - - in armature
90 - - in friction + foucault currents
390 - intake at full load = 3.25 amp. @ 120 volts.

Speed 2050 revs. p. min: at light load, but strong field, and finely laminated armature.

Armature Dimensions

External diam.	6"	15.24
Internal -	4"	10.16.
Extreme breadth	1.182"	3.00
Core -	0.662"	1.68
Groove		4.2
Depth of groove	0.26"	0.66
Breadth -	0.24"	0.61

Winding
72 wires in each groove
9 layers of 8 turns each.
Body insulation 0.01" 0.025"
Space 0.22" broad 0.25" deep.
Wire # 26 B.W.G. 0.018" covered to 0.0265
Space occupied 0.242" broad 0.239" deep.
42 Commutator bars
Length of wire 1008'
Weight - - 0.99 lb.
Res - - 32 ω = 8 ω between brushes 9.2 volt

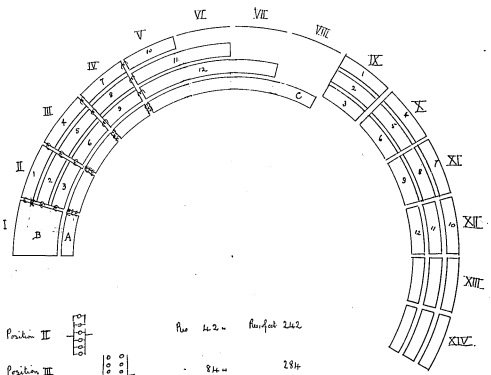
Drop in armature at full load 30.7 volts
Energy - - - 102 Watts.
Flux through semi ring 55,500
Total useful flux 111,000
Mean # in core space (4.27) = 13,000

Field. Allowing a total flux of 200,000 and a mean density of 15,500. the wrought iron core diametric area = 12.9 □ cm.
- mitis iron - - = 14.2 □ cm.

The wrought iron diameter = 4.05 = 1.595" or 1.6" say
mitis - - = 4.25 = 1.673" or 1.675".

The trial field winding may be 2 lbs: of copper wire having a res: of 1 ω = 0.5 ω per lb. = # 16 B.S. or # 18. B.W.G. preferably
the formula = 500'. The mean diameter being 2.1", the mean circ: = 6.6 0.55' or with mitis iron 0.6' = 880 turns = 12.0 layers of 67 turns = 0.72" depth of winding = 3.04" ext: diam.
For outline of armature, see the sketch for ¾ HP p. 26 which is correct representation for this armature in all but breadth of core & no. 9 layers of 50 turns each on the experimental field-winding

Horse Power		Edison Mf. Co.	Edison New System	Pennt	Jenney July 1895	Jen Reader Pat	Connecticut	Rikon	Detroit	Excelsior	Sprague	G+R	Franklin Model
	Revs. per min.		2400 1200	2500 - 2200		2000						3000	2,100
	Voltage		120	120		110						110	110
	Net weight		20	17½		15						18	2½
⅛	Floor space		7½x7½x8½	7½x7½x8½									9¾x7¾x11
	Pulley			1½"									
	Unit price		$60	$32		$32							$32
	Revs. per min.	2100	2500 1400	2000		1500			2400		2000		1500
	Voltage	110	120	256 120		104 220			110		110		110
¼	Net weight	90	29	50		45			75		52		65
	Floor space	16¾x13½"							6"x14"		14½x9½x14½		14¾x9¾x14½
	Pulley	3½x2x3"		2"x					2"x2"		2¼x1¾"		3x2
	List price	$65.69	$100	$90.		$90			$90				
	Revs. per min.	2100	1700 1300	2000	3000	2500	2000	2400	2200		1900		1400
	Voltage	110	120 240	25 6 120		110 220	110	220 220	110		110		110 - 220
½	Net Weight	120	36	70	130	70	130		114		130		94½
	Floor Space	24½x16½		?	8½x7½x7"		14¾x10¾		7½"x18½"				18½x11½"
	Pulley	5½x2½x4"		2.5"	3"x1½"		5½"	3"x3"	3"x2"				2½"x3"
	List Price	$103.25	$125 $77.25 6 pulleys	$130		$120	$130	$140	$130				3½ x 3" $130
	Revs. per min.	1800	1500 1050	1800		1500	2000	1500	2000	2100	1800		1300
	Voltage	110	120 240 500	60 220		110 220	110	55 220	110	110	110		110 - 220
1	Net Weight	270	113	182			290		180	137	202		157
	Floor space	24½x22½	14½x10½x8½	22½x16½			14½x10½		8½"x22"	14"x22"			22½ x 12½x8½
	Pulley	4"x5½x11"	10"x2½"	6"x2½"		4"x	5½x2½	4"x3"	4½"x3½"	4"x3"	4½"x3½"		4 x 4
	List Price	$159.25		$160		$150	$160	$150	$160	$160			$160
	Revs. per min.			1500		1400	1800	1500	1900	2000	1650		1290
	Voltage			60 220		110 220 500	110	55 220	110	110	110		110 3 phase
2	Net weight			200			450		292	270	329		290
	Floor space						16½x13½"		9½"x24½"	24"x14"	25½"x10½"		22½x15½x18½
	Pulley			4"		6"	5½x3"	5"x3½"	5½x3½"	5"x3½"	5"x3"		6"x3"
	List Price			$250		$200	$250	$200	$250	$250			?
	Rev. per min	1475											
	Voltage	125											
3½	Net Weight	550											
	Floor space	32½x26½											
	Pulley	7½x5½x8											
	List Price	$282.75											



Position II	Res	42 ω	Res for set 242
Position III		84 ω	284
Position IV		125 ω	325
Position V		167·5 ω	367·5
Position VI		200 ω	400
Position VII		250 ω	450
Position VIII		333 ω	533
Position IX		~~416~~ 416 ω	616
Position X		500 ω	700
Position XI		583 ω	783
Position XII		666 ω	866
Position XIII		750 ω	950
Position XIV		833 ω	1033

Test of the Carrying Capacity of six Switches on porcelain bases, received from the Newyorth Works.

10th January. These switches were as follows.

# 1	One	120	light switch double pole
# 2	One	60	" " "
# 3	One	30	" " "
# 4	One	15	" " "
# 5	One	10 ?	" " "
# 6	One	10 ?	" " two way & single pole.

The 120 light switch was used with 126 lamps (56·25 amp) successfully, ~~but~~ for five minutes without any appreciable heating and no dangerous spark. If used however as a single pole switch as as to break the circuit at one opening or pair of springs, the arc followed up, and remained for a little while.

The 60 light switch was used with 30 lamps (38·03 amp) successfully without overheating or dangerous sparking.

The 30 light switch was used with 30 lamp (20·84 amp) successfully and even with 100 lamps without any difficulty.

The 15 light switch was used with up to 65 lamps on.

The 10 " " " " " " 50 " "

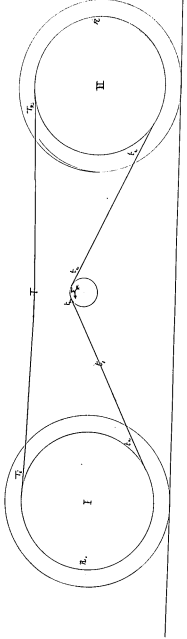
The 10 " 2 way " " " " 5 " "

Design for a Lamp Resistance in the field circuit of the No 2 Car Motor.

Allowing 110 volts lamps of 16 cp and 0·45 amp. = 245 ω res: but say 250 ω at working temp. With these data we have the following table :-

No of Point	Group	Res:	Total res: in cct.	Current in 500 volts	Current per lamp	Res: if one series of lamps fail	Total res: in cct.	Current per lamp	Res: if two series of lamps fail	Total Res: in cct.	Current per lamp
II	1 of 6	42	242	2·066	0·3442	50	250				
III	2 . 6	84	284	1·760	0·280	100	300				
IV	3 . 6	125	325	1·538	0·256	150	350				
V	4 . 6	167·5	367·5	1·363	0·227	200	400				
VI	5 . 6	200	400	1·250	0·250	250	450				
VII	6 . 6	250	450	1·111	0·278	333	533				
VIII	4 . 3	333	533	0·938	0·312	500	700				
IX	5 . 3	416	616	0·822	0·271	625	825				
X	6 . 3	500	700	0·714	0·238	750	950				
XI	7 . 3	583	783	0·639	0·213	875	1075				
XII	8 . 3	666	866	0·578	0·193	1000	1200				
XIII	9 . 3	750	950	0·527	0·176	1125	1325				
XIV	10 . 3	833	1033	0·484	0·161	1250	1450				
XV											

Diagram of Sprocket chain and pulleys.
Scale 1" = 1 foot.



Problem:- To determine the power capable of being exerted by a Sprocket chain on the car.

The tension on the belt between the large pulleys is that due to the catenary pull due to a given sag, and weight of belt per foot. The tension on the lower halves may be approximated to as $\frac{1}{2}$ that on the centre suspension and $\frac{1}{4}$ on the outer suspension of the catenary pull if level.

Let F be the pull delivered to the belt by the armature in lbs. weight
- t_1, t_2 . . catenary pulls on the belt at point of union with pulleys
- T_1 T_2 . . . . . above . . . .
- μ . . coeff. of friction between belt and pulley
- R_1, R_2 . . resisting forces of the car against the chain.

Then the driving condition for R_2 is

$$R_2 = F + t_2 - T_2$$

Since the arc of embrace is about 190°,

$F + t_2 = 2.07 R$ $T_2 = 1.03 R$ for iron upon iron

$F + t_2 = 1.35 R$ $T_2 = 0.345 R$ - - - wood.

The pull $F = \frac{25000}{2} = 12500$ lbs.

as that $T_2 = 12.00$ lbs for iron upon iron

and $T_2 = 4630$ - - iron - wood.

The weight of the chain is 8.7 lbs. per foot. = 26 lbs. per half span

For iron against iron $T_2 = 50$ [illegible] times the half span weight

- - - wood $T_2 = 16$ - - - -

Determination of Obach and Standard Galvanometer Constants
11th Feb. 91

Copper electrolytic cell. Plates 13.8 × 7.6 immersing 68.5 sq. cms. on each side. in solution of $CuSO_4$ sp. g. 1.10 @ 17°c

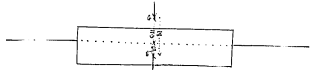
	Weight of Plates before test	Weight of plates after test	Gain	Loss	Accepted transfer	Time of test, Seconds.	Mean Tangent	Accepted mean current	Time per amp	Mean of possible curr	Amps for Tan 1.
A	39.3090	38.6375	0.2285		0.3295	585	0.32164 obach	1.7082 amp	0.18807		5.329
B	39.2265	38.9018		0.3247	=0.0056152 per sec						
A+B	77.5365	77.5393					2.07836	1.2280	0.2280		0.81143 making R = 0.202
Sum	77.5358	77.5393									

Pressure measured at Mr Burke's house 21 o'clock 16th Jany. 1891
118 volts at centre of distribution. 116 lowest.

Determination of Obach & Standard Galvanometer Constants
21st Jan. 91.

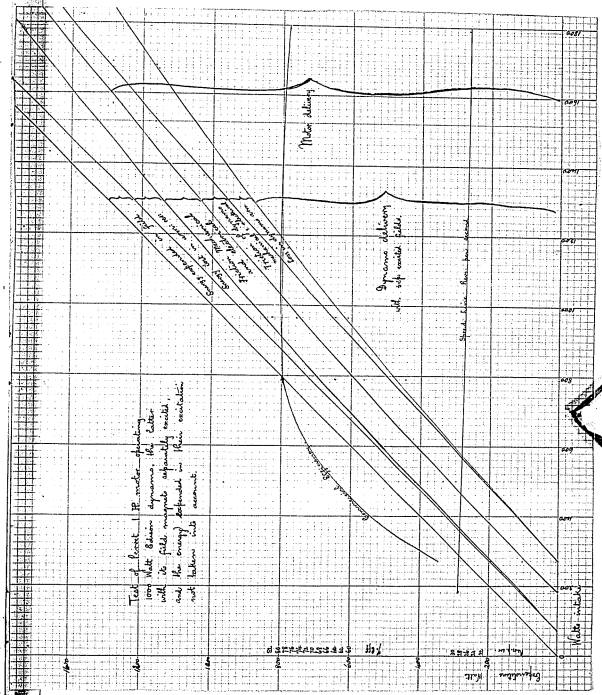
Copper electrolytic cell. same plates as above. Courtney battery. same solution.

	Weight of plate before test	Weight of plate after test	Gain	Loss	Accepted Transfer	Time of test Seconds	Mean Tangent	Accepted mean current	Time per amp	Amps for Tan 1.	H
A	38.3995	42.1738	3.7743		3.7743	12,120	0.182	0.9482 amp	0.1919	5.211	
B	39.8242	35.0181		3.8061							
							1.223 g		1.290	0.7752	0.192



C = S = 187,200 g. λ = 18.

No. of obs.	P.D. on terminals	Shunt Difference	Current absorbed by motor	Current in field	Energy in field	Current in armature	Energy in armature	Drop in armature	E.M.F. generated by motor	Energy developed in Watts	Speed R.P.M.	Speed C.P.S.
1	volts	volts	0·108	0·568	59·2	c	0	0			—	
2	132·0	121·75	0·286	1·505	"	2·937	114·1	0·77	121·0	183·4	1735	28·92
3	2	"	0·365	1·937	"	1·369	166·7	1·13	120·6	165·1	1720	28·67
4	2	"	0·422	2·221	"	1·653	201·3	1·36	120·4	199·0	1700	28·33
5	4	121·0	0·780	4·105	0·564	68·2	3·537	427·9	2·92	118·1	447·8	1690	28·25
6	5	120·	1·170	6·158	0·560	67·2	5·590	670·8	4·61	115·4	645·1	1695	28·25
7	9	120·	1·925	5·026	0·560	67·2	7·458	895·0	6·15	113·8	848·8	1688	28·13
8	11	119·5	1·85	9·736	0·558	66·7	9·168	1096·0	7·56	112·0	1027·0	1660	27·67
9	10	119·0	2·175	11·465	0·555	66·1	10·892	1295·0	8·98	110·0	1197·0	1650	27·5
10	8	119·0	2·425	12·76	0·555	66·1	12·192	1451·0	10·06	108·9	1328·0	1620	27·0
11	15	118·8	2·675	14·08	0·554	66·	13·512	1605·0	11·15	107·6	1454·0	1605	26·75
12	14	118·7	2·700	14·21	0·554	65·8	13·642	1620·0	11·25	107·4	1465·0	1605	26·75
13	12	119·4	2·900	15·24	0·557	66·5	14·692	1754·	12·12	107·3	1576·0	1600	26·67
14	13	118·3	2·875	15·13	0·552	65·3	14·562	1723·	11·22	104·1	1576·0	1575	26·25


Motor delivery
Dynamo delivery
Speed curve when run as motor
Speed curve when run as dynamo
Speed when run as motor
Speed when run as dynamo
Speed when run as motor
Speed when run as dynamo
Test of Current & HP motor absorbing
when Watts delivered
when field energized differently
and the energy developed in Main
and balance with
Commercial efficiency
Brake horse power
Watts input
Watts output

Test of a Perret 1 H.P. Motor, labelled #1095

type C, C.E. 110 volts 1.8 amperes, revs. p.m. about 1800. Running
Silk bounded facing commutator, dept 8th 1890, W.N. Dickinson Jr.

This motor weighs on its base with pulley attached 192 lbs. Its bed plate weighs 32 lbs. It was submitted in the large tank with its axis 14.6 from the tank floor. The tank was immersed to a depth of 13.14 cms, so that it displaced 187200 c.c.

The resistances of the armature (hot) = 0.825 ω.
" " field (hot) = 2.15 ω.

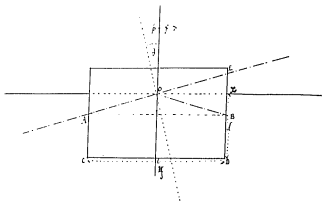
The motor was coupled with a 1000-Watt Edison dynamo, separately excited, whose armature had a resi (hot) = 1.01 ω.

Volts	Reading	Moment	Volts recorded from curves	Watts Moment	Energy delivered	Friction Watts	Mech. Efficiency	Electrical Efficiency	Volts at Dynamo terminals	Revs: Exciter / Motor / Dynamo	Current Amperes	Energy Watts	No. of Lamps
–	–		4.185			113.14	00	0.62	–	–			–
–	–		4.185			113.14	00	0.62	–	–			–
250 ω / 1000	16	4000	4.207	2466x10⁷	70.7 / 66.1	94.14	0.30 / 0.34	0.70	–	–			–
250 ω / 1000	23.5	5875	4.25	3622 -	102.6 / 95	96.14	0.379 / 0.36	0.736	–	–			–
250 ω / 1000	33.4 / 10	19,400	4.18	11.96 -	338.0 / 319	78.8	0.680 / 0.64	0.841	126.2 / 125.7	0.23343	1.733	227.3 / 216.1	4
250 ω / 1000	29 / 28	32,250	4.085	1989 -	562.1 / 590	83.0	0.761 / 0.799	0.873	118.8 / 118.5	0.43324	3.574	396.0 / 424.3	8
250 ω / 1000	44.7 / 39	43,700	4.0746	26.95 -	758.0 / 798	80.8	0.787 / 0.818	0.882	113 / 112.8	0.70673	5.236	601.6 / 640.6	12
250 ω / 1000	52 / 50	54,300	4.0748	33.48 -	926.2 / 922	19 0.8	0.746 / 0.793	0.883	111.5 / 112.0	0.92439	6.850	784.4 / 852.6	16
1000	60	60,000	4.00	37.0 -	1017 / 1090	190. ?	0.747 ? / 0.801	0.878	110 / 110.2	1.10037	8.521	937.5 / 1005	20
250 ω / 1000 / 1000	3 / 20 / 60	70,750	4.033	43.62 -	1178 / 1262	150.	0.776 / 0.865	0.875	107 / 108.1	1.327804	9.830	1052 / 1161	24
250 ω / 1000	20 / 66	80,000	4.023	49.33 -	1320 / 1320	134.	0.789 / 0.801	0.869	105 / 117.0	1.482256	10.98	1123 / 1285	28
"		80,000	4.016	49.33 -	1320 / 1320	134.	0.783 / 0.795	0.868	105 / 117.0	1.482256	10.98	1123 / 1285	28
250 ω / 1000 ω	3 / 60	85,750	4.023	52.18 -	1410 / 1422	166.	0.774 / 0.790	0.865	102 / 116.6	1.647925	12.21	1246 / 1423	32
250 ω / 1000 ω / 1000	20 / 64	81,250	3.966	50.10 -	1315 /	201.	0.750 / 0.735	0.847	101 / 114.8	1.60033	11.86.	1198 / 1362	32

The efficiency of this motor when supplying any power p (watts) and supplied with 120 volts is approximately expressed by the equation

$$\eta = \frac{p}{P} = \frac{0.825\,(P-65)^2 - 165}{P}$$

Particulars of this motor. 416 wire on armature 4 layer of 4 turns each and 26 sections. 26 commutator bars. 2 brushes = 0.081 ω ?
18 B+S. wire on the armature = 3.3 ω = 2.6 lbs.
Wire on field 0.034" enel. = 0.025" = # 22 B+S. = 24 lbs. in all. 6 magnets
Field cores are composed of 90 plates. Length of armature 27.5 from commutator to end of winding. Diameter of commutator 7.65
Brush width 3.5. Diameter of armature over all 10.0
" " shaft 1.95



Problem – A rectangular tank is l cms. long, b broad, and h high. Its axis of flotation is vertical, and perpendicular to the base. It immerses to a depth of d cms. Its center of inertia is situated on the axis at an height c from the base, and a force whose moment is f acts round a horizontal axis perpendicular to the side l and passing through the axis of flotation at an point p on the axis of flotation distant s from the base. Determine the limiting angle θ of deviation.

The mass ABB$_2$C is $bl\left(d - \frac{1}{2}t\tan\theta\right)$. Its center of inertia is distant $\frac{1}{2}\left(d - \frac{1}{2}t\tan\theta\right)$ from H along the axis OH, or $d - \left(\frac{d}{2} - \frac{1}{4}t\tan\theta\right)$ from p.

The mass AOB is $bl\frac{t}{2}\left(\frac{t}{2}\tan\theta\right)$. Its c.i. is distant $d - \frac{2}{3}\left(\frac{t}{2}\tan\theta\right)$ from H along the axis, or $d - \left(d - \frac{t}{6}\tan\theta\right)$ from p.

The mass BOE is $bl\frac{t}{2}\left(\frac{t}{2}\tan\theta\right)$. Its c.i. is distant $\frac{2}{3}\times\frac{t}{2}$ from O

The compound mass ~~base~~ AOEDC, has its x abscissa of c.i.

$$\frac{\frac{t}{2}\times bl\frac{t}{2}\tan\theta}{bld} = \frac{t^2}{12d}\tan\theta = x$$

Its ordinate $-y$ is

$$\frac{bl\left(d - \frac{t}{2}\tan\theta\right)\left(\frac{t}{4}\tan\theta + \frac{d}{2}\right) + \frac{bl}{2}\left(\frac{t}{3}\tan\theta\right)\frac{t}{4}\tan\theta}{bld}$$

$$-y = \left(1 - \frac{t}{2d}\tan\theta\right)\left(\frac{t}{4}\tan\theta + \frac{d}{2}\right) + \frac{t^2\tan^2\theta}{24d}$$

Now resolving moments about the point p.

the force f = $-f$

– mass bld = $+ bldg\ (s - c)\sin\theta$

– buoyancy $bldg$ = $+ bldg\{(x\cos\theta + y\sin\theta) + (s - d)\sin\theta\}$

$\therefore f = bldg\{(s-c)\sin\theta + x\cos\theta + y\sin\theta + (s-d)\sin\theta\}$

$\frac{f}{bldg} = \sin\theta\ (s - d) + x\cos\theta + y\sin\theta$

$= \sin\theta\ (s - d - y) + x\cos\theta$

for θ to be a maximum under given conditions $s = d + y$

or in other words the center of inertia of the tank should coincide with the center of buoyancy of the displaced water. This represents a condition of neutral equilibrium, and of instability for the tank. The rule is therefore to load the tank as lightly as possible, but having as given load to bring its center of inertia nearly up to the metacentre

Table for Copper Platinoid Wire @ 20°C. from data of opposite page. B.W.G.

B.W.G.	B.&S.	Diameter	Circular	Weight		Length		Resistance	
				lbs per foot	Ozs per foot	Feet per lb	Feet per ozs	Ohms per lb	Ohms per ft
1	0000	.4600	211,600	0.64642	10.343	1.5796	25.0405	0.0000796	0.0000479
0000	4	0.4564	208,116	0.6246	9.9936	1.6010	25.9700	0.0000755	
000		0.4125	170,625	0.5472	8.5152	1.8274	29.500	0.0000111	
00	000	0.3648	133,772	0.5058	8.0928	1.9767	31.620	0.0000124	
0		0.3310	109,561	0.4376	6.1116	2.2853	36.5930	0.0000156	
1	00	0.3065	93,960	0.3203	5.1248	3.1224	49.958	0.0000213	
2	1	0.2893	83,694	0.3189	5.1024	3.1361	50.178	0.0000214	
3	2	0.2576	66,358	0.2811	4.4976	3.5578	56.925	0.0000243	
4	3	0.2294	52,624	0.1956	3.1296	5.1125	81.800	0.0000349	
5	4	0.2043	41,738	0.1551	2.4816	6.4477	103.163	0.0000441	
6	5	0.1819	33,100	0.1230	1.9680	8.1301	130.082	0.0000556	
7	6	0.1620	26,244	0.0975	1.5600	10.2564	164.103	0.0000701	
8	7	0.1443	20,822	0.0773	1.2368	12.9366	206.986	0.0000884	
9	8	0.1285	16,512	0.0613	0.9808	16.3132	261.011	0.0001115	
10	9	0.1144	13,087	0.0486	0.7776	20.5761	329.218	0.0001407	
11	10	0.1019	10,384	0.0386	0.6176	25.9067	414.507	0.0001772	
12	11	0.0907	8,226	0.0305	0.4880	32.7869	524.590	0.0002243	
13	12	0.0808	6,529	0.0242	0.3872	41.3223	661.157	0.0002827	
14	13	0.0720	5,184	0.0192	0.3072	52.0833	833.333	0.0003563	
15	14	0.0641	4,109	0.0152	0.2432	65.7895	1052.632	0.0004500	
16	15	0.0571	3,260	0.0121	0.1936	82.6446	1322.314	0.0005653	
17	16	0.0508	2,581	0.0095	0.1520	105.2632	1684.211	0.0007200	
18	17	0.0453	2,052	0.0076	0.1216	131.5789	2105.263	0.0009000	
19	18	0.0403	1,624	0.0060	0.0960	166.6667	2666.667	0.0011392	
20	19	0.0359	1,288	0.0048	0.0768	208.3333	3333.333	0.0014240	
21	20	0.0320	1,020	0.0038	0.0608	263.1579	4210.526	0.0017992	
22	21	0.0285	810.0	0.0030	0.0480	333.3333	5333.333	0.0022784	
23	22	0.0253	642.1	0.0024	0.0384	416.6667	6666.667	0.0028480	
24	23	0.0226	509.5	0.0019	0.0304	526.3158	8421.053	0.0035978	
25	24	0.0201	404.0	0.0015	0.0240	666.6667	10666.667	0.0045568	
26	25	0.0179	320.4	0.0012	0.0192	833.3333	13333.333	0.0056960	
27	26	0.0159	254.1	0.0009	0.0144	1052.6316	16842.105	0.0071910	
28	27	0.0142	201.6	0.0007	0.0112	1351.3514	21621.622	0.0092340	
29	28	0.0126	159.8	0.0006	0.0096	1666.6667	26666.667	0.0113920	
30	29	0.0113	126.7	0.0005	0.0080	2083.3333	33333.333	0.0142400	
31	30	0.0100	100.5	0.0004	0.0064	2564.1026	41025.641	0.0182784	
32	31	0.0089	79.70	0.0003	0.0048	3333.3333	53333.333	0.0227840	
33	32	0.0080	63.21	0.0002	0.0032	4166.6667	66666.667	0.0284800	
34	33	0.0071	50.13	0.0002	0.0032	5263.1579	84210.526	0.0359784	
35	34	0.0063	39.75	0.0001	0.0016	6666.6667	106666.667	0.0455680	
36	35	0.0056	31.52	0.0001	0.0016	8333.3333	133333.333	0.0569600	
37	36	0.0050	25.00	0.0001	0.0016	10526.3158	168421.053	0.0719568	
38		0.0045	19.83	0.0000	0.0008	13333.3333	213333.333	0.0911360	
39		0.0040	15.72	0.0000	0.0008	16666.6667	266666.667	0.1139200	
40		0.0035	12.47	0.0000	0.0008	21052.6316	336842.105	0.1439136	

Copper wire @ 60°C.

Platinoid wire @ 20°C

Weight		Length		Resistance		Length		Resistance		Diameter
lbs per foot	Ozs per foot	Feet per lb	Feet per ozs	Ohms per lb	Ohms per ft	Feet per lb	Feet per ozs	Ohms per lb	Ohms per ft	
0.64642	10.343	1.5796	25.0405	0.0000796	0.0000479	0.9352	14.963	0.0001722	0.0001036	0.460
0.6246	9.9936	1.6010	25.9700	0.0000755	0.0000454	0.9673	15.477	0.0001664	0.0001001	0.4564
0.5472	8.5152	1.8274	29.500	0.0000111	0.0000387	0.9673	15.477	0.0001664	0.0001001	0.4564
0.5058	8.0928	1.9767	31.620	0.0000124	0.0000345	0.9673	15.477	0.0001664	0.0001001	0.4564
0.4376	6.1116	2.2853	36.5930	0.0000156	0.0000298	1.1244	17.990	0.0001432	0.0000861	0.4125
0.3203	5.1248	3.1224	49.958	0.0000213	0.0000218	1.3065	20.904	0.0001232	0.0000741	0.3648
0.3189	5.1024	3.1361	50.178	0.0000214	0.0000217	1.3065	20.904	0.0001232	0.0000741	0.3648
0.2811	4.4976	3.5578	56.925	0.0000243	0.0000191	1.4819	23.710	0.0001086	0.0000653	0.3310
0.1956	3.1296	5.1125	81.800	0.0000349	0.0000133	2.1307	34.092	0.0000755	0.0000454	0.2893
0.1551	2.4816	6.4477	103.163	0.0000441	0.0000106	2.6851	42.962	0.0000599	0.0000360	0.2576
0.1230	1.9680	8.1301	130.082	0.0000556	0.0000084	3.3846	54.154	0.0000475	0.0000285	0.2294
0.0975	1.5600	10.2564	164.103	0.0000701	0.0000067	4.2654	68.247	0.0000377	0.0000226	0.2043
0.0773	1.2368	12.9366	206.986	0.0000884	0.0000053	5.3763	86.021	0.0000299	0.0000179	0.1819
0.0613	0.9808	16.3132	261.011	0.0001115	0.0000042	6.7751	108.401	0.0000237	0.0000142	0.1620
0.0486	0.7776	20.5761	329.218	0.0001407	0.0000033	8.5397	136.635	0.0000188	0.0000113	0.1443
0.0386	0.6176	25.9067	414.507	0.0001772	0.0000026	10.7643	172.229	0.0000149	0.0000089	0.1285
0.0305	0.4880	32.7869	524.590	0.0002243	0.0000021	13.5685	217.096	0.0000118	0.0000071	0.1144
0.0242	0.3872	41.3223	661.157	0.0002827	0.0000016	17.1037	273.659	0.0000094	0.0000056	0.1019
0.0192	0.3072	52.0833	833.333	0.0003563	0.0000013	21.5625	345.000	0.0000074	0.0000044	0.0907
0.0152	0.2432	65.7895	1052.632	0.0004500	0.0000010	27.1867	434.987	0.0000059	0.0000035	0.0808
0.0121	0.1936	82.6446	1322.314	0.0005653	0.0000008	34.2701	548.322	0.0000047	0.0000028	0.0720
0.0095	0.1520	105.2632	1684.211	0.0007200	0.0000006	43.2099	691.358	0.0000037	0.0000022	0.0641
0.0076	0.1216	131.5789	2105.263	0.0009000	0.0000005	54.4662	871.458	0.0000029	0.0000017	0.0571
0.0060	0.0960	166.6667	2666.667	0.0011392	0.0000004	68.6813	1098.901	0.0000023	0.0000014	0.0508
0.0048	0.0768	208.3333	3333.333	0.0014240	0.0000003	86.5801	1385.281	0.0000018	0.0000011	0.0453
0.0038	0.0608	263.1579	4210.526	0.0017992	0.0000003	109.1703	1746.725	0.0000014	0.0000009	0.0403
0.0030	0.0480	333.3333	5333.333	0.0022784	0.0000002	137.6771	2203.634	0.0000011	0.0000007	0.0359
0.0024	0.0384	416.6667	6666.667	0.0028480	0.0000002	173.6111	2777.778	0.0000009	0.0000005	0.0320
0.0019	0.0304	526.3158	8421.053	0.0035978	0.0000001	218.9781	3503.650	0.0000007	0.0000004	0.0285
0.0015	0.0240	666.6667	10666.667	0.0045568	0.0000001	276.0331	4416.530	0.0000005	0.0000003	0.0253
0.0012	0.0192	833.3333	13333.333	0.0056960	0.0000001	348.0836	5569.338	0.0000004	0.0000002	0.0226
0.0009	0.0144	1052.6316	16842.105	0.0071910	0.0000001	439.0313	7024.501	0.0000003	0.0000002	0.0201
0.0007	0.0112	1351.3514	21621.622	0.0092340	0.0000001	553.7396	8859.834	0.0000002	0.0000001	0.0179
0.0006	0.0096	1666.6667	26666.667	0.0113920	0.0000001	683.1058	10929.693	0.0000002	0.0000001	0.0159
0.0005	0.0080	2083.3333	33333.333	0.0142400	0.0000001	853.8823	13662.117	0.0000001	0.0000001	0.0142
0.0004	0.0064	2564.1026	41025.641	0.0182784	0.0000000	1051.3158	16821.053	0.0000001	0.0000000	0.0126
0.0003	0.0048	3333.3333	53333.333	0.0227840	0.0000000	1351.3514	21621.622	0.0000001	0.0000000	0.0113
0.0002	0.0032	4166.6667	66666.667	0.0284800	0.0000000	1724.1379	27586.207	0.0000000	0.0000000	0.0100
0.0002	0.0032	5263.1579	84210.526	0.0359784	0.0000000	2173.9130	34782.609	0.0000000	0.0000000	0.0089
0.0001	0.0016	6666.6667	106666.667	0.0455680	0.0000000	2777.7778	44444.444	0.0000000	0.0000000	0.0080
0.0001	0.0016	8333.3333	133333.333	0.0569600	0.0000000	3448.2759	55172.414	0.0000000	0.0000000	0.0071
0.0001	0.0016	10526.3158	168421.053	0.0719568	0.0000000	4347.8261	69565.217	0.0000000	0.0000000	0.0063
0.0000	0.0008	13333.3333	213333.333	0.0911360	0.0000000	5555.5556	88888.889	0.0000000	0.0000000	0.0056
0.0000	0.0008	16666.6667	266666.667	0.1139200	0.0000000	6896.5517	110344.828	0.0000000	0.0000000	0.0050
0.0000	0.0008	21052.6316	336842.105	0.1439136	0.0000000	8695.6522	139130.435	0.0000000	0.0000000	0.0045
0.0000	0.0008	26666.6667	426666.667	0.1822720	0.0000000	11111.1111	177777.778	0.0000000	0.0000000	0.0040
0.0000	0.0008	33333.3333	533333.333	0.2278400	0.0000000	13888.8889	222222.222	0.0000000	0.0000000	0.0035

Weight		Length		Resistance		Diameter
lbs per foot	Ozs per foot	Feet per lb	Feet per ozs	Ohms per lb	Ohms per ft	
0.9352	14.963	1.0695	17.112	0.0001722	0.0001036	0.460
0.9673	15.477	1.0338	16.540	0.0001664	0.0001001	0.4564
0.9673	15.477	1.0338	16.540	0.0001664	0.0001001	0.4564
0.9673	15.477	1.0338	16.540	0.0001664	0.0001001	0.4564
1.1244	17.990	0.8894	14.230	0.0001432	0.0000861	0.4125
1.3065	20.904	0.7654	12.247	0.0001232	0.0000741	0.3648
1.3065	20.904	0.7654	12.247	0.0001232	0.0000741	0.3648
1.4819	23.710	0.6749	10.798	0.0001086	0.0000653	0.3310
2.1307	34.092	0.4693	7.509	0.0000755	0.0000454	0.2893
2.6851	42.962	0.3725	5.960	0.0000599	0.0000360	0.2576
3.3846	54.154	0.2954	4.727	0.0000475	0.0000285	0.2294
4.2654	68.247	0.2344	3.751	0.0000377	0.0000226	0.2043
5.3763	86.021	0.1860	2.976	0.0000299	0.0000179	0.1819
6.7751	108.401	0.1476	2.361	0.0000237	0.0000142	0.1620
8.5397	136.635	0.1171	1.873	0.0000188	0.0000113	0.1443
10.7643	172.229	0.0929	1.487	0.0000149	0.0000089	0.1285
13.5685	217.096	0.0737	1.179	0.0000118	0.0000071	0.1144
17.1037	273.659	0.0585	0.935	0.0000094	0.0000056	0.1019
21.5625	345.000	0.0464	0.741	0.0000074	0.0000044	0.0907
27.1867	434.987	0.0368	0.588	0.0000059	0.0000035	0.0808
34.2701	548.322	0.0292	0.466	0.0000047	0.0000028	0.0720
43.2099	691.358	0.0231	0.370	0.0000037	0.0000022	0.0641
54.4662	871.458	0.0184	0.293	0.0000029	0.0000017	0.0571
68.6813	1098.901	0.0146	0.233	0.0000023	0.0000014	0.0508
86.5801	1385.281	0.0115	0.185	0.0000018	0.0000011	0.0453
109.1703	1746.725	0.0092	0.147	0.0000014	0.0000009	0.0403
137.6771	2203.634	0.0073	0.116	0.0000011	0.0000007	0.0359
173.6111	2777.778	0.0058	0.092	0.0000009	0.0000005	0.0320
218.9781	3503.650	0.0046	0.073	0.0000007	0.0000004	0.0285
276.0331	4416.530	0.0036	0.058	0.0000005	0.0000003	0.0253
348.0836	5569.338	0.0029	0.046	0.0000004	0.0000002	0.0226
439.0313	7024.501	0.0023	0.036	0.0000003	0.0000002	0.0201
553.7396	8859.834	0.0018	0.029	0.0000002	0.0000001	0.0179
683.1058	10929.693	0.0015	0.023	0.0000002	0.0000001	0.0159
853.8823	13662.117	0.0012	0.018	0.0000001	0.0000001	0.0142
1076.700	17227.207	0.0009	0.014	0.0000001	0.0000000	0.0126
1351.896	21630.342	0.0007	0.011	0.0000001	0.0000000	0.0113
1724.138	27586.207	0.0006	0.009	0.0000001	0.0000000	0.0100
2173.913	34782.609	0.0005	0.007	0.0000000	0.0000000	0.0089
2777.778	44444.444	0.0004	0.006	0.0000000	0.0000000	0.0080
3448.276	55172.414	0.0003	0.005	0.0000000	0.0000000	0.0071
4347.826	69565.217	0.0002	0.004	0.0000000	0.0000000	0.0063
5555.556	88888.889	0.0002	0.003	0.0000000	0.0000000	0.0056
6896.552	110344.828	0.0001	0.002	0.0000000	0.0000000	0.0050
8695.652	139130.435	0.0001	0.002	0.0000000	0.0000000	0.0045
11111.111	177777.778	0.0001	0.001	0.0000000	0.0000000	0.0040
13888.889	222222.222	0.0000	0.001	0.0000000	0.0000000	0.0035

1.26448 (17) 133.079 0.4033 5193 2.480 12.890 0.0001548 0.0007738

30303.634 2834.658

4,539.0 11,270 0.0002204 0.0009878 2.179 2.8814 5747.9 0.0001825 0.0364B

Light Cable

Light Cable Copper

Cable (28 S.W.G. & 36 S.W.G.)

23 S.W.G. Copper wire per mile.

Pure Copper @ 100° C.				German Silver @ 20° C.				
Weight		Resistance		Weight		Resistance		Diameter
Lbs. per thou.	Feet per ohm	Ohms per ft.	Ohms per lb.	Lbs. per thou.	Feet per ohm	Ohms per ft.	Ohms per lb.	Inches
19.240	15910	0.0001884	0.0097286	6.249	1005	0.001590	0.0009947	
9.631	15.000	0.001533	0.0039652	5946	9774	0.001676	0.0009421	0.1400
7.722	13.850	0.001846	0.0007362	4837	9554	0.002184	0.0009421	0.1257
6.410	12.600	0.002029	0.0006938	3948	7764	0.002531	0.0009421	0.1150
4.799	10.860	0.002109	0.0004210	3123.8	6.1393	0.003015	0.0009421	0.0996
3.098	8.888	0.003287	0.0001181	1967.6	5.1401	0.004787	0.0009421	0.0795
2.537	7.943	0.003580	0.0001551	1576.4	4.5941	0.005981	0.0009421	0.0711
1.8113	6.766	0.003620	0.0001078	1133	3.9127	0.008395	0.0009421	0.0606
1.515	6.289	0.003649	0.0000890	983.3	3.6373	0.009242	0.0009421	0.0563
1.482	6.164	0.003698	0.0000869	961.32	3.5667	0.009453	0.0009421	0.0552
1.237	5.744	0.003853	0.0000725	863.21	3.1907	0.010567	0.0009421	0.0495
1.093	5.401	0.003957	0.0000641	708.9	2.6209	0.012860	0.0009421	0.0441
0.931	4.961	0.004134	0.0000546	604.0	2.2333	0.015086	0.0009421	0.0394
0.731.0	4.361	0.004369	0.0000429	474.2	1.7532	0.019218	0.0009421	0.0351
0.630.5	3.956	0.004636	0.0000370	408.7	1.5109	0.022299	0.0009421	0.0312
0.533.6	3.629	0.004834	0.0000313	345.9	1.2789	0.026348	0.0009421	0.0278
0.396.5	3.159	0.005274	0.0000232	257.1	0.9505	0.035450	0.0009421	0.0234
0.386.7	3.099	0.005386	0.0000226	250.6	0.9265	0.036348	0.0009421	0.0228
0.340.4	2.888	0.005680	0.0000199	220.6	0.8155	0.041293	0.0009421	0.0214
0.286.1	2.633	0.006109	0.0000167	185.4	0.6855	0.049132	0.0009421	0.0195
0.253.1	2.467	0.006492	0.0000148	164.0	0.6063	0.055547	0.0009421	0.0183
0.168.8	2.047	0.007824	0.0000098	109.4	0.4045	0.083281	0.0009421	0.0150
0.158.7	1.972	0.008317	0.0000092	102.8	0.3800	0.088656	0.0009421	0.0144
0.109.3	1.647	0.009960	0.0000063	70.84	0.2618	0.12866	0.0009421	0.0120
0.098.72	1.567	0.010465	0.0000057	64.00	0.2365	0.14243	0.0009421	0.0114
0.073.62	1.360	0.012052	0.0000043	47.73	0.1764	0.19098	0.0009421	0.0099
0.062.07	1.242	0.013211	0.0000036	40.24	0.1487	0.22657	0.0009421	0.0091
0.047.26	1.083	0.015117	0.0000027	30.63	0.1132	0.29763	0.0009421	0.0079
0.039.92	0.9803	0.016713	0.0000023	25.87	0.09561	0.35233	0.0009421	0.0071
0.032.11	0.8933	0.020763	0.0000018	20.81	0.07691	0.43801	0.0009421	0.0063
0.024.25	0.7806	0.022914	0.0000014	15.71	0.05807	0.58000	0.0009421	0.0055
0.018.55	0.678.4	0.029941	0.0000011	12.02	0.04443	0.75787	0.0009421	0.0047
0.016.41	0.6253	0.033844	0.0000009	10.64	0.03933	0.85611	0.0009421	0.0044
0.012.87	0.5489	0.038543	0.0000007	8.344	0.03084	1.0919	0.0009421	0.0039
0.009.79	0.4969	0.042580	0.0000005	6.347	0.02346	1.4353	0.0009421	0.0034
0.008.29	0.4569	0.046324	0.0000004	5.376	0.01987	1.6947	0.0009421	0.0031
0.006.65	0.4129	0.051280	0.0000003	4.312	0.01594	2.1126	0.0009421	0.0028
0.005.65	0.3878	0.054602	0.0000003	3.662	0.01354	2.4866	0.0009421	0.0026
0.004.79	0.3578	0.059222	0.0000002	3.107	0.01148	2.9312	0.0009421	0.0024
0.004.06	0.3298	0.064246	0.0000002	2.634	0.009737	3.4569	0.0009421	0.0022
0.003.44	0.3048	0.069520	0.0000001	2.233	0.008257	4.0770	0.0009421	0.0020
0.002.92	0.2818	0.075210	0.0000001	1.894	0.007004	4.8064	0.0009421	0.0018
0.002.47	0.2608	0.081305	0.0000001	1.606	0.005940	5.6681	0.0009421	0.0016
0.002.09	0.2418	0.087844	0.0000001	1.362	0.005037	6.6835	0.0009421	0.0015
0.001.77	0.2248	0.094944	0.0000001	1.155	0.004270	7.8800	0.0009421	0.0013
0.001.50	0.2088	0.102600	0.0000001	0.9797	0.003621	9.2923	0.0009421	0.0012
0.001.27	0.1938	0.110900	0.0000001	0.8309	0.003071	10.958	0.0009421	0.0011
0.001.08	0.1798	0.119900	0.0000001	0.7047	0.002604	12.922	0.0009421	0.0010
0.000.913	0.1668	0.129600	0.0000001	0.5977	0.002208	15.239	0.0009421	0.0009
0.000.774	0.1548	0.140100	0.0000001	0.5070	0.001873	17.972	0.0009421	0.0008
0.000.656	0.1438	0.151500	0.0000001	0.4300	0.001588	21.195	0.0009421	0.0007
0.000.557	0.1338	0.163800	0.0000001	0.3647	0.001347	24.995	0.0009421	0.0006
0.000.472	0.1238	0.177100	0.0000001	0.3093	0.001142	29.478	0.0009421	0.0005
0.000.401	0.1148	0.191400	0.0000001	0.2623	0.0009686	34.763	0.0009421	0.0004
0.000.340	0.1068	0.206900	0.0000001	0.2225	0.0008217	40.997	0.0009421	0.0003
0.000.289	0.0988	0.223600	0.0000001	0.1887	0.0006968	48.341	0.0009421	0.0003
0.000.244	0.0918	0.241700	0.0000001	0.1601	0.0005911	57.010	0.0009421	0.0002
0.000.208	0.0858	0.261200	0.0000001	0.1358	0.0005014	67.232	0.0009421	0.0002
0.000.176	0.0798	0.282300	0.0000001	0.1152	0.0004253	79.281	0.0009421	0.0002
0.000.150	0.0748	0.305000	0.0000001	0.0977	0.0003608	93.500	0.0009421	0.0001
0.000.127	0.0698	0.329600	0.0000001	0.0829	0.0003061	110.23	0.0009421	0.0001
0.000.108	0.0648	0.356200	0.0000001	0.0703	0.0002596	129.98	0.0009421	0.0001
0.000.091.7	0.0608	0.384900	0.0000001	0.0597	0.0002203	153.29	0.0009421	0.0001
0.000.077.8	0.0568	0.415900	0.0000001	0.0506	0.0001869	180.78	0.0009421	0.0001
0.000.066.0	0.0528	0.449400	0.0000001	0.0430	0.0001586	213.19	0.0009421	0.0001
0.000.056.0	0.0498	0.485500	0.0000001	0.0364	0.0001345	251.41	0.0009421	0.0001
0.000.047.5	0.0468	0.524500	0.0000001	0.0309	0.0001142	296.51	0.0009421	0.0001
0.000.040.3	0.0438	0.566600	0.0000001	0.0262	0.0000969	349.70	0.0009421	0.0001
0.000.034.2	0.0408	0.612000	0.0000001	0.0223	0.0000822	412.40	0.0009421	0.0001
0.000.029.0	0.0378	0.661000	0.0000001	0.0189	0.0000698	486.40	0.0009421	0.0001
0.000.024.6	0.0348	0.714000	0.0000001	0.0160	0.0000592	573.70	0.0009421	0.0001
0.000.020.9	0.0328	0.771400	0.0000001	0.0136	0.0000503	676.60	0.0009421	0.0001
0.000.017.7	0.0298	0.833100	0.0000001	0.0116	0.0000427	798.10	0.0009421	0.0001
0.000.015.0	0.0278	0.899600	0.0000001	0.0098	0.0000363	941.30	0.0009421	0.0001
0.000.012.7	0.0258	0.971600	0.0000001	0.0083	0.0000308	1110.0	0.0009421	0.0001
0.000.010.8	0.0238	1.049000	0.0000001	0.0071	0.0000262	1309.0	0.0009421	0.0001
0.000.009.1	0.0218	1.133000	0.0000001	0.0060	0.0000222	1544.0	0.0009421	0.0001
0.000.007.7	0.0198	1.224000	0.0000001	0.0051	0.0000189	1821.0	0.0009421	0.0001
0.000.006.5	0.0178	1.322000	0.0000001	0.0043	0.0000160	2147.0	0.0009421	0.0001
0.000.005.5	0.0168	1.428000	0.0000001	0.0037	0.0000136	2532.0	0.0009421	0.0001
0.000.004.6	0.0148	1.542000	0.0000001	0.0031	0.0000115	2986.0	0.0009421	0.0001
0.000.003.9	0.0138	1.666000	0.0000001	0.0026	0.0000098	3521.0	0.0009421	0.0001
0.000.003.3	0.0128	1.799000	0.0000001	0.0022	0.0000083	4153.0	0.0009421	0.0001
0.000.002.8	0.0118	1.943000	0.0000001	0.0019	0.0000070	4897.0	0.0009421	0.0001
0.000.002.3	0.0108	2.098000	0.0000001	0.0016	0.0000059	5776.0	0.0009421	0.0001
0.000.001.9	0.0098	2.266000	0.0000001	0.0013	0.0000050	6812.0	0.0009421	0.0001
0.000.001.6	0.0088	2.447000	0.0000001	0.0011	0.0000042	8034.0	0.0009421	0.0001
0.000.001.3	0.0078	2.643000	0.0000001	0.0009	0.0000036	9476.0	0.0009421	0.0001
0.000.001.1	0.0068	2.855000	0.0000001	0.0008	0.0000030	11180	0.0009421	0.0001
0.000.000.9	0.0058	3.084000	0.0000001	0.0006	0.0000025	13190	0.0009421	0.0001
0.000.000.7	0.0048	3.331000	0.0000001	0.0005	0.0000021	15560	0.0009421	0.0001
0.000.000.6	0.0038	3.597000	0.0000001	0.0004	0.0000018	18360	0.0009421	0.0001
0.000.000.5	0.0028	3.885000	0.0000001	0.0003	0.0000015	21660	0.0009421	0.0001
0.000.000.4	0.0018	4.196000	0.0000001	0.0002	0.0000012	25550	0.0009421	0.0001
0.000.000.3	0.0008	4.532000	0.0000001	0.0002	0.0000010	30150	0.0009421	0.0001
0.000.000.2	0.0008	4.895000	0.0000001	0.0001	0.0000008	35570	0.0009421	0.0001
0.000.000.2	0.0008	5.287000	0.0000001	0.0001	0.0000007	41960	0.0009421	0.0001
0.000.000.1	0.0008	5.710000	0.0000001	0.0001	0.0000006	49510	0.0009421	0.0001
0.000.000.1	0.0008	6.167000	0.0000001	0.0001	0.0000005	58410	0.0009421	0.0001
0.000.000.1	0.0008	6.661000	0.0000001	0.0001	0.0000004	68910	0.0009421	0.0001
0.000.000.1	0.0008	7.194000	0.0000001	0.0001	0.0000003	81290	0.0009421	0.0001
0.000.000.1	0.0008	7.770000	0.0000001	0.0001	0.0000003	95910	0.0009421	0.0001
0.000.000.1	0.0008	8.391000	0.0000001	0.0001	0.0000002	113100	0.0009421	0.0001
0.000.000.1	0.0008	9.063000	0.0000001	0.0001	0.0000002	133400	0.0009421	0.0001
0.000.000.1	0.0008	9.788000	0.0000001	0.0001	0.0000002	157400	0.0009421	0.0001
0.000.000.1	0.0008	10.570000	0.0000001	0.0001	0.0000001	185700	0.0009421	0.0001
0.000.000.1	0.0008	11.410000	0.0000001	0.0001	0.0000001	219000	0.0009421	0.0001
0.000.000.1	0.0008	12.320000	0.0000001	0.0001	0.0000001	258400	0.0009421	0.0001
0.000.000.1	0.0008	13.310000	0.0000001	0.0001	0.0000001	304800	0.0009421	0.0001
0.000.000.1	0.0008	14.370000	0.0000001	0.0001	0.0000001	359600	0.0009421	0.0001
0.000.000.1	0.0008	15.520000	0.0000001	0.0001	0.0000001	424200	0.0009421	0.0001
0.000.000.1	0.0008	16.760000	0.0000001	0.0001	0.0000001	500400	0.0009421	0.0001
4.031	10.004	0.0003261	0.0000.03996	24.614	632.1	0.0001025	0.0001582	0.0648

Data for the compilation of wire tables.

Let ρ be the resistivity of the metal in ohms per c.c.
" d " diameter of wire in (inches thousandths) mils
" σ " specific gravity of the material

Then the res: per cm:	$= \frac{\rho}{\pi\left(\frac{2.54}{1000}\right)^2 \frac{d^2}{4}}$	$= 197.355\ \frac{\rho}{d^2}$
" ohms per foot	$= \frac{30.48\ \rho}{\pi\ (2.54)^2\ \frac{d^2}{4} \times 10^6}$	$= \frac{6.012.4440}{d^2}\ \frac{\rho}{10^6}$
" feet per ohm	$= \frac{\pi\ (2.54)^2 d^2}{4 \times 30.48 \times 10^6}$	$= 1.6684\ \frac{d^2}{\rho} \times 10^{-7}$
" weight gm per cm:	$= \frac{\pi}{4}\left(\frac{2.54}{10}\right)^2 d^2 \sigma$	$= 5.0671 \times 10^{-6}\ d^2\sigma$
" lbs "	$= \frac{\pi}{4}\ (2.54)^2 d^2 \sigma$ / 453.6 × 10³	$= 1.1171 \times 10^{-6}\ d^2\sigma$
" " foot	$= \frac{\pi}{4}\ (2.54)^2 d^2 \sigma\ 30.48$ / 453.6 × 10³	$= 3.404 \times 10^{-7}\ d^2\sigma$
" feet per lb	$= \frac{4 \times 453.6 \times 10^3}{\pi\ (2.54)^2 d^2 \sigma \times 30.48}$	$= 2.937 \times 10^6\ \frac{1}{d^2\sigma}$
" ohms per lb	$= \frac{4 \times 30.48 \times 10^6 \times 10^{-6} \times 453.6 \times 10^{-6}}{\pi\ (2.54)^2 \times d^2 \times \pi\ (2.54)^2 d^2 \sigma \times 30.48}$	$= 1.7666 \times 10^{-13}\ \frac{\rho}{d^4\sigma}$
" lbs. per ohm	$= \frac{\pi^2 \times (2.54)^4\ d^4 \sigma}{16 \times 453.6 \times \rho \times 10^{-6}}$	$= 5.66\ \rho b \times 10^{-6}\ \frac{d^4\sigma}{\rho}$

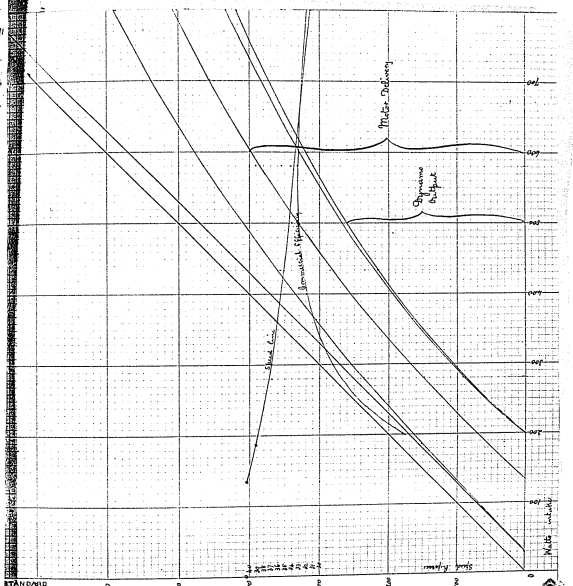
This values of these coefficients for different metal are as follows:

Metal		ρ abs. units	$\frac{\rho}{\sigma}$ from above (10⁻⁶)	$\sqrt{\frac{\rho}{\sigma}}$	σ	$\frac{1}{\sigma}$	$\frac{\rho}{\sigma^2}$	$\sqrt{\frac{\rho}{\sigma^2}}$
Pure soft copper (Matthey)		1593.5	1.5930 × 10⁻⁶	6.2755 × 10⁻⁴	8.940 1.1178	1.7886 × 10⁻⁴	5.6159 × 10⁻⁶	5.5455 × 10⁻³
"	20°C	1717	1.717 × 10⁻⁶	5.8241 × 10⁻⁴	"	1.7886	1.9223	1.3862
"	55°C	1931	1.934 × 10⁻⁶	5.1706 × 10⁻⁴	"	1.9186	2.1627	1.4706
"	60°C	1964	1.964		"	1.9231	2.1980	1.4826
"	100°C	2212	2.212		"	2.0161	2.4756	1.5734
Fine hard copper (Matthey)		1630	1.630 × 10⁻⁶	6.1350 × 10⁻⁴	8.90 1.1124	1.7241 × 10⁻⁴	5.4914 × 10⁻⁶	5.4914 × 10⁻³
"	20°C	1757	1.757 × 10⁻⁶	5.6925 × 10⁻⁴	"	1.7886	5.0740 × 10⁻⁶	5.0740 × 10⁻³
German Silver	0°C	20.700	2.07 × 10⁻⁵	4.8309 × 10⁻³	8.68 1.1102	2.3148 × 10⁻⁴	2.3848 × 10⁻⁶	1.5443 × 10⁻³
		34610 in Hg	3.246 × 10⁻⁵	3.0805 × 10⁻³		3.9936 × 10⁻⁴	3.6933 × 10⁻⁶	1.9218 × 10⁻³
	25°C	20,850	2.085 × 10⁻⁵	4.7962 × 10⁻³		2.3148 × 10⁻⁴	2.4055 × 10⁻⁶	1.5510 × 10⁻³
		34,970	3.30 × 10⁻⁵	3.0303 × 10⁻³		3.9936 × 10⁻⁴	4.032 × 10⁻⁶	2.0079 × 10⁻³
Platinoid	0°C	40,200	4.02 × 10⁻⁵	2.4876 × 10⁻³	8.78 1.1348	2.4876 × 10⁻⁴	4.5785 × 10⁻⁶	2.1394 × 10⁻³
	20°C	40,770	4.037 × 10⁻⁵	2.4771 × 10⁻³	"	2.4876 × 10⁻⁴	4.5979 × 10⁻⁶	2.1453 × 10⁻³
Aluminium	0°C	2,881	2.881 × 10⁻⁶	3.471 × 10⁻³	2.81 0.5997	3.5587 × 10⁻⁴	1.0253 × 10⁻⁶	1.0126 × 10⁻³
	20°C	3,104	3.104 × 10⁻⁶	3.2216 × 10⁻³	"	3.5587 × 10⁻⁴	1.0690 × 10⁻⁶	1.0339 × 10⁻³

One circular mil foot of Matthews soft copper = 0°C. 20°C. 10.371 Ω 11.124 Ω 10.371 Ω
" " " " " " 8.1126 " 8.7016 " 8.1126 "
" " " " " " 10.4156 " 11.1756 " 10.4156 "

Expansion							
Pure copper	0°	13,000	1.2 × 10⁻⁶	8.38 × 10⁻⁴	7.8 1.1236	1.539 × 10⁻⁶	6.148 × 10⁻³
Differences	20°	13,160	1.316 × 10⁻⁶	7.6 × 10⁻⁴	7.8 1.1236	1.697 × 10⁻⁶	5.928 × 10⁻³
only use spot	60°	15,460	1.546 × 10⁻⁶	6.468 × 10⁻⁴	7.8 1.1236	2.092 × 10⁻⁶	5.035 × 10⁻³
resistance coils	100°	17,760	1.776 × 10⁻⁶	5.631 × 10⁻⁴	7.8 1.1236	2.571 × 10⁻⁶	4.340 × 10⁻³

No. of Obs.	F.D. at motor terminals	Blank	Amps.	Energy in motor watts	Current in field amps.	Energy in field watts	Current in armature amps.	Energy in armature watts	Available head in water	E.M.F generated by armature	Energy equiv. to head in effect	Speed R.p.m.	Power R.p.s.	Eff. per cent.
1	121.50	0.045	0.237	28.8	0.237	28.8	-					-		
2	"	0.209	1.10	133.6	"	"	0.863	104.8	3.32	119.2	102.	2420	40.33	2.931
3	"	0.292	1.537	186.8	"	"	1.300	158.0	4.70	116.8	151.8	2350	39.17	2.98.
4	"	0.310	1.632	198.3	"	"	1.395	169.5	5.46	116.3	162.3	2270	37.83	3.07.
5	"	0.439	2.311	280.8	"	"	2.074	251.0	7.88	113.6	235.6	2215	36.92	3.077
6	121.	0.571	3.006	365.7	"	"	2.769	334.9	11.08	109.9	304.3	2185	36.42	3.012
7	"	0.690	3.58	435.2	"	"	3.343	404.4	14.01	107.	357.7	2105	35.09	3.033
8	"	0.912	4.80	598.5	"	"	4.563	552.0	20.05	101.9	465.0	2042	34.03	2.981
9	"	1.270	6.682	868.8	"	"	6.447	780.0	29.66	97.3	588.7	1880	31.33	2.915
10														-
11														-



STANDARD
SECTION.
No. 88.

Test of C + C. ½ H.P. Motor 17th Jan. 91.

Marked type 3N ⁄ 976 110 volts – Ampère 2000 Revs per min.

The motor was mounted in the large tank, and coupled to the 1000-Watt Edison dynamo, which had resistance inserted in its field circuit in order to reduce the generated emf.

Load Pending	Moment	Moment ×6165	Driving Watts	Efficiency (Testing)	Mech. Efficiency	Electrical efficiency	P.D. at dynamo terminals	Ampère Revs Target	Ampère	Volts at terminals	E.M.F. generated	Energy absorbed Watts	
								1·1379					
–				102									–
0 @ 5	12·50	7·708	30·19	120·6			120						–
5 @ 12	30·00	18·50	69·98	92·3			110						–
12 @ 26	65·000	40·08	148·0	87·6			108·	0·18944	0·939	0·8	108·9	96·3	a λ
250 @ 40	10,000	61·65	224·5	79·9			105·	0·21256	1·565·	1·5	106·5	165·7	2 λ
250 @ 52·5	13,125·	80·92	284·0	73·7			101	0·31051	2·286	2·2	103·2	235·9	6 λ
250 @ 67·5	16,875·	104·03	354·7	110·3			105·	0·41763	3·074	3·0	108·2	332·6	8 λ
250 @ 80 500 @ 20	22,500	138·70	423·5·	154·2			109·5	0·5·1983	3·827	3·8	113·3	433·6	10 λ
													–
													–

Three C + C. motor weighs 90 lbs. and occupies a cubical space of 20" × 11" × 15". The resistance of its armature between brushes is 3·5ω cold 4·6ω hot.

. . . . field coils is 447ω cold + 515ω hot.

There are 27 bars in its commutator and diam = 2·16". width of face 1⅞".

The armature is gramme type with 27 sections diam 4¼" over all. Bore of field 4⅞"

Determination of the specific gravity of some samples of Aluminium, German Silver and Platinoid. 19th Jan. 91.

Aluminium wire #1 coiled up

Weight in air		0·1055 g.	
" Aq. Dest:	0·0675		
	0·0380	4 g.	2·776
#2 " " "	air	0·1282	
" "	Aq. dest:	0·0829	
	0·0453	Sp g	2·830

Since the danger is to make the sp g. too small owing to adherent air bubbles the latter observation may be taken as having weight (3), and this makes the mean 2·812, = 2·809 at 4°

German silver wire #1 coiled up

Weight in air		2·0093 g	
" Aq. Dest:	1·7779		
	0·2314	Sp g	8·684
" " #2 " " "	in air	2·1361	
" "	Aq. Dest:	1·8814	
	0·2457	" "	8·686
" " #3 " " "	in air	2·0455	
" "	Aq. Dest:	1·8106	" "
	0·2349		8·706
This result corrected for temp = 8·682		Mean	8·692

Platinoid (Smith Mfg. Co.) Wire #1 coiled up

Weight in air		1·8492	
" Aq. Dest:	1·3740		
	0·1752	Sp. g:	8·844
" #2 coiled up "	Weight in air	1·8029	
"	Aq. Dest:	1·3314	
	0·1712	Sp. g:	8·778
Plate	Weight in air	2·6319	
"	Aq. Dest	2·3315	
	0·3004	Sp. g:	8·760
This result corrected for temp = 8·783		Mean	8·794

Temp. of the distilled water 18° C.

On the best size of platinoid wire to employ for connecting the ½ H.P. & ¼ H.P. motor armatures to their commutators.

The res: of one coil of wire on the 500-Watt (¼ H.P.) armature is 0·8 ω (hot) and the res: of the platinoid connectors about 0·6 ω. or 0·75 of the coil res. This proportion is successful, with the usual short-circuiting one coil or two coils, and until found deficient may be adopted. The res: of the armature with three wires in the proportion of $\frac{3}{4}$ to $\frac{3}{4}$ + 0·75. For ¼ H.P. = $\frac{1.4 \times 3}{4.0}$ = 1·125 (4 H.P. motor)

The res: of one coil of the ½ H.P. motor is 1·6 ω hot

" " " " platinoid connectors should then be 1·2 ω

= 4·8 ω per foot = 0·007" = 0·018 cm. diam.

In the 500-watt machine, the res: of one coil is 8·0 ω, and the resistance of one platinoid wire will be 0·75 ω. = 3·0 ω per foot = 0·009" = 0·035 cm.

Constants of the Ring Tangent + Coarse-Wire Siemens Tan: Galvanometer 22nd Jan. 91.

No. of Obs.	Tan. of Sol. ϕ	Ampère	Tangent of Ring	Constant	Mean Constant.		Tangent of Siemens	Constant	Mean Constant.	
1	1·5108	1·169	0·151165	0·1126			9·51436	8·1140		
2	1·85246	1·439	0·16286	0·1133	0·1137		11·1430	7·950		
3	2·8229	2·190	0·252442	0·1152			19·081	8·71		

32	.000	66	.102
33	.003	67	.105
34	.006	68	.108
35	.009	69	.111
36	.012	70	.114
37	.015	71	.117
38	.018	72	.120
39	.021	73	.123
110	.024	74	.126
41	.027	75	.129
42	.030	76	.132
43	.033	77	.135
44	.036	78	.138
45	.039	79	.141
46	.042	80	.144
47	.045	81	.147
48	.048	82	.150
49	.051	83	.153
50	.054	84	.156
51	.057	85	.159
52	.060	86	.162
53	.063	87	.165
54	.066	88	.168
55	.069	89	.171
56	.072	90	.174
57	.075	91	.177
58	.078	92	.180
59	.081	93	.183
60	.084	94	.186
61	.087	95	.189
62	.090	96	.192
63	.093	97	.195
64	.096	98	.198
65	.099	99	.201

Meteorological Records

Date		Barometer Reading: Inches	Tenths	Hundredths	Corrected for 0°C	Mean	Thermometer Reading: Min.	Dry	Wet	Evapn. in Inches	Winds	Remarks
November 1890	28											
	29											
	30											
December	1st											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	10											
	11											
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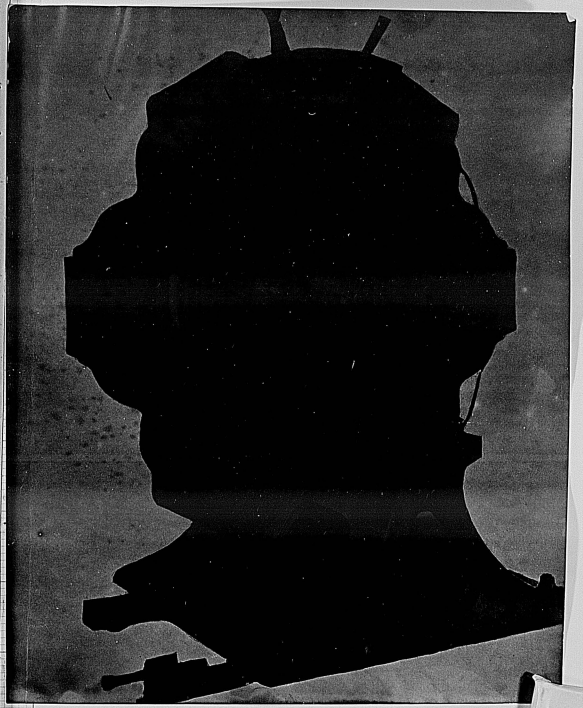
	28											
	29											
	30											
	31											
Jan. 1891	1											



Volts at Terminals. (No load reading)

Saturation Curve
of 30 kilowatt Stahlheber Dynamo
Field separately excited
No current in armature.

Ampere effective readings from curve

Efficiency Characteristic of 30 kilowatt
dynamo, at 360 r.p.m. and working

Abstract of a Report by Mr Kolben of the first tests on the new 20-Kwt Edison Multipolar machine just completed at Schenectady Works

Blue-prints of the machine and its details are preserved for reference.

6 Poles. 125 volts. 160 Amps. 1000 r.p.m. Weight 3070 lbs.

Armature. Body 175 lbs. of # 24 B&S. oxydized iron wire.
Winding 204 divs 3 turns in each making 612 turns in all (gramme ring) in one layer. Triangular cross connections.

Field winding 68 lbs. of # 9 B&S on each core 1405 lbs. in all. cores in series total resistance 8·16 ω. 8520 turns per core.

1st Test. Fields separately excited, and p.d. observed at armature terminals with no current supplied. Speed uniform @ 980 r.p.m. Results shewn on curve sheet inserted.

2nd Test. The resistance in the field circuit was adjusted to give 125 volts at brushes with 200 amperes output in the main circuit. The load was then reduced and the E.M.F observed.

3d Test. The drop in the field rec: box was observed with varying load, and constant B.M.F of 125 volts at terminals.

B.M.F. at M.T. v.	Current in main cct: amp.	Current in shunt "	Drop in Field box v	Speed r.p.m.	Remarks
12·5	0	9·75	4·5	1015	Steam low
"	75	11·5	3·2	980	and engine not
"	120	12·1	2·6	978	regulating well.
"	140	12·75	2·1	978	
"	160	13·25	1·6	950	
"	200	15	0·4	930	

4th Test. Heating.
After 11 hours run with 120 volts and 160 amp.
rise of temp. on field 19°C
" " armt 37°C.

" 2¾ " " " 120 volts and 200 amp.
rise of temp. on field 25°C
" " armt 40°C.

5th Sparking.
The machine ran perfectly sparkless with a load of 160 ⌐ 120 very slight sparking being noticeable at 200 ⌐ and this was most probably due to the inaccurate division of the commutator. No moving of the brushes was necessary in reducing the load from 200 to 120 amperes, from 120 to 80, from 80 to one load, if the volts & r.p.m. were kept constant by the resistance box. Brushes could be moved at no load and full field 1½" or 7 bars without producing sparking.

A note is added pointing out the large reluctance of the iron wire armature, and its prejudicial effects.

A telegram of the 20th Jan: announced that a cast iron bushing ⅛" thick enclosing the armature had greatly improved the machine, saving the field energy from 1140 to 800 w.

Summary of Meteorological Observations at Newfoth City during the year 1820, as received in a letter addressed to Mr. Edison from L. N. Jesimofski Sergt: of Signal Corps.

Air pressure in inches. Mean reduced to 32° F 23.86
" " " 32° F and sea level 30.06
Highest reading " " " Jan 15th 30.77
Lowest " " " Oct. 23rd 29.35
Annual range 1.42
Mean monthly range 0.87

Mean hourly values

1 am	30.06	6 am	30.06	11 ock.	30.07	16 ock.	30.02	21	30.06
2	30.05	7	30.07	Noon	30.05	17	30.03	22	30.06
3	30.05	8	30.07	13	30.04	18	30.03	23	30.06
4	30.05	9	30.07	14	30.03	19	30.04	Mit.	30.06.
5	30.06	10	30.07	15	30.02	20	30.04		

Air temperature F. degrees
Mean 54°, Highest July 8th 95°, Lowest Mon. 7th 6°, Annual range 89°, Greatest daily range, Feby. 7th 40°. Least daily range Sept. 11th 4°. Greatest monthly range March 65°. Least monthly range 8°. (June). Mean of absolute monthly range 45°. Mean daily range 15°.
Mean hourly values

1 am	50°	7 ock.	49	13 ock.	56	19 ock.	55
2	50	8	50	14	57	20	54
3	50	9	51	15	57	21	53
4	49	10	52	16	56	22	53
5	49	11	54	17	56	23	52
6	49	12	55	18	56	24	51

Number of days Max: below 32°. Jany. 2, Feby 1, Mar, 4 Nov: 1 Dec. 7
Total number of days 15
Number of days min: below 32°. Jan: 15, Feby 11, Mar. 15. Apr. 3. Nov 4. Dec. 23. Total 71
Number of days max: above 90° July 4 days
First ice formed Nov. 21st, last ice formed Apr. 1st

Humidity Mean dewpoint, degrees. 43°F. Mean relative humidity 73%.

Cloudiness Mean 0.54 Greatest mean monthly Feby + Mar. 0.68
least mean monthly, June 0.51
There were 82 cloudless days, 150 partly cloudy, + 133 cloudy days.

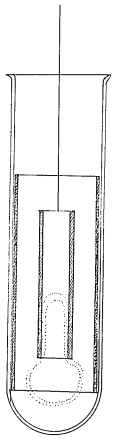
Wind. Prevailing direction NW. Aggregate integral 98,784 miles
Greatest monthly aggregate integral Dec. 11,231, miles Least Sept. 6,534 miles
Highest velocity from NW. 55 miles per hour Jan. 22nd.
Number of times blowing from the N. (from 20 obs: daily) 91, NE, 72, E, 22, SE, 90 S. 114, SW. 106, W. 91, NW 154, Calm 0.
Mean hourly values. (miles)

1 ock	11	7 ock.	10	13 ock.	13	19 ock.	12
2	10	8	10	14	13	20	11
3	10	9	11	15	13	21	11
4	10	10	12	16	13	22	11
5	10	11	13	17	12	23	10
6	10	Noon	13	18	12	24	11

Precipitation (from Snow, rain hail, + sleet.)
Total: 52.3". Total depth of snowfall 45.6". distributed as follows—
Jany. have Feby 4.0"; Mar. 21.3". Apr. 1.2". Nov twice, Dec. 19.1".
The last snow of season occurred Apr. 1st First snow Nov. 27th.
Greatest monthly precipitation in Sept. 8.21". Least in Nov. 0.82".
Greatest precipitation in any consecutive 24 hours Sept 16-17th 5.12".
The average annual precipitation at N. Y. City (for the past 20 years) = 43.54".
For each month Jany. 3.76" Feby. 3.69". Mar. 3.88" Apr. 3.27". May 3.05". June 3.26", July 4.36". Aug. 4.84". Sept 3.34". Oct. 3.36". Nov. 3.52". Dec. 3.21".

There have been 1146 days on which 0.01" or more of rain or melted snow occured. Thunderstorms occurred as follows— in Mar: 1, Apr. 3, May 5, June 9, July 3, Aug 9, Sept. 5, Oct. 1.
The last frost of season occurred Apr. 1st
" first " " Oct. 5th.

Full-size Cross Section of Meter Tube showing zinc cylinder electrode.

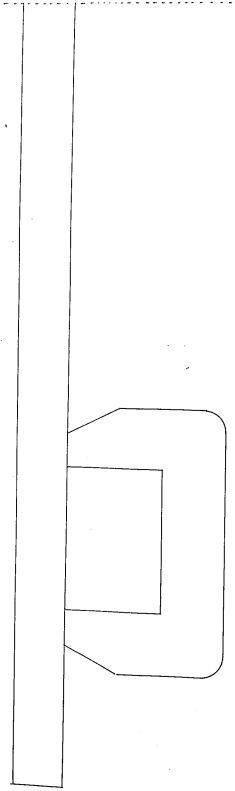


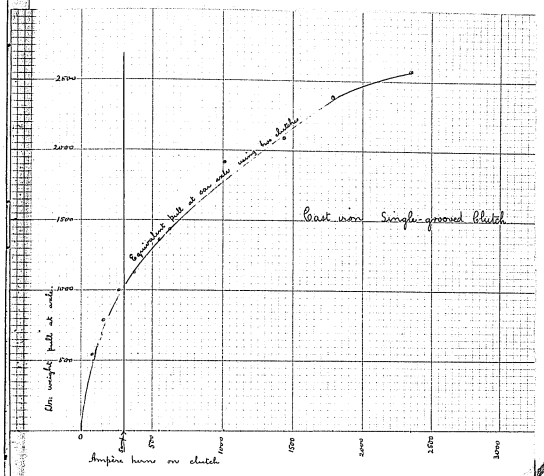
Tests of new Edison Electrolytic Meter. Jan. 23rd

This instrument consists of a delicate clock spring (escapement spring) supporting a cylinder of zinc weighing 22 gms. immersed in a solution of $ZnSO_4$ 1.18. The position of the spring is shown by a pointer moving over a dial in a vertical plane. Before being finally set up, the suspended zinc cylinder was bored out to a larger internal diameter, and a glass bulb with a tubulated end was inserted into this, as shown by the dotted lines. This bulb helped to float the cylinder, and reduces the load on the small spring. A film of kerosene oil was poured on the surface of the zinc sulphate solution. The suspending wire was of fine platinum, and rested on a little brass pulley about 0.5 diam. The recording dial was of german silver and graduated into a circle of degrees. The resistance of the cell and suspension was 30Ω when first set up. The current was started at 16.50. 23rd 5 mas. and was interrupted for 3 hours on the following morning. The suspended cylinder was the anode. The needle indicated −1° at starting and +5° after 21 hours = 0.3° per hr.

21°	.	47	.
25°	.	61	.
39°	.	76	
56		133	
90	.	360°	Then reversed current.

Section of electromagnetic parts of actual clutch. Taken through the cross
Axis
Full size





Data for the Calculation of Problems connected with the Electro-deposition of Silver in $Ag_2Cr_2H_2Cr_2$ Solution

The resistances of two experimental cells were observed to solve some measurements were comparatively rough, but may serve some practical purposes.

The dimensions of the cells were:— Right Cylinders.

Height 4·0 . Internal Rad: 2·0 . Ext: rad: 3·9.

Solution in # 1 — 1 part Ag_2Cr_2 10 parts K_2Cr_2 50 parts H_2O

" " # 2 — 1 " " 10 " " 100 " "

Resistance of # 1 0·3 ω Resistance of # 2 0·35 ω

by bridge 1000/100 = 1000/100 . 4 Leclanché cells . Temp. 18°C.

If ρ be the resistivity of the liquid, R and r the radii, h the height, ω the resistance

$$dw = \frac{dr}{2\pi r h}\rho$$

$$\omega = \frac{\rho}{2\pi h}\int_r^R \frac{dr}{r}$$

$$= \frac{\rho}{2\pi h}\log_e \frac{R}{r}$$

$$\rho = \frac{2\omega\pi h}{\log_e \frac{R}{r}} \quad \therefore \rho_1 = \frac{2 \times 0{\cdot}3 \times 3{\cdot}14 \times 4}{0{\cdot}6678} = 11{\cdot}29 \text{ ω per c.c.}$$

$$\rho_2 = \frac{2 \times 0{\cdot}35 \times 3{\cdot}14 \times 4}{0{\cdot}6678} = 13{\cdot}17 \text{ ω " "}$$

Test of electromagnetic clutch 24th Jan. 91.

The section of this clutch is represented on the opposite page. It was wound with 17½ lbs. of # 9 B.W.G. in 60 turns (10 layers of 6) The follower clutch is of cast iron, and the face plate is also of cast iron. The measurement was made with slipping friction and not with starting friction. Res: of clutch 0·125 ω cool.

No.	Clutch Depth Inch	Radius	Pull observed lbs wt	Moment Pot-lbs	Current amperes $\times 2^1$	Ampère turns. $\times 2^1$	MMF $\times 2^1$	Normal stress ω $\frac{\text{Pot-lbs}}{\text{Radius}^2 \times 2^2}$	Stress per sq in.	Stress regions 15 cm.	Bulk of Core $\frac{\text{Radius}^2 \times \pi \times \text{depth}}{231}$	Bulk of Core $\frac{\text{Radius}^2 \times \pi \times \text{depth}}{2^3 \times 231}$
1	2×0·089	12·5"	70	67·2	2·322	339·3	175	538	22·8	6·69	538	6300
2	2×0·240		103	98·9	5·22	313·	393	791	33·6	2·36	792	7680
3	2×0·34		130	124·8	8·57	532.	668	999	42·4	2·98	1000	8630
4	2×0·48		147	141·1·2	12·52	751·	944	1130	48·0	3·05	1120	9195
5	2×0·71		178	170·0	18·52	1111	1396	1360	57·8	4·07	1360	11,095
6	2×0·8		186	178·5	20·87	1252.	1574	1430	60·7	4·27	1430	10,340
7	2×1·27		248	238	33·65	2019.	2538	1902	80·8	5·68	1920	11,925
8	2×1·814		273	262	48·0	2880.	3620	2100	89·0	6·26	2096	12,500
9	2×2·275		310	297·6	59·35	3561.	4475	2376	101·	7·10	2380	13,320
10	2×3·00		335	322	78·26	4696.	5900	2576	109·	7·67	2576	13,890

The determinations of total stress, and of E in this table are only estimates, since the acting coefficient is unknown, and the action is referred to the mean radius of the clutch.

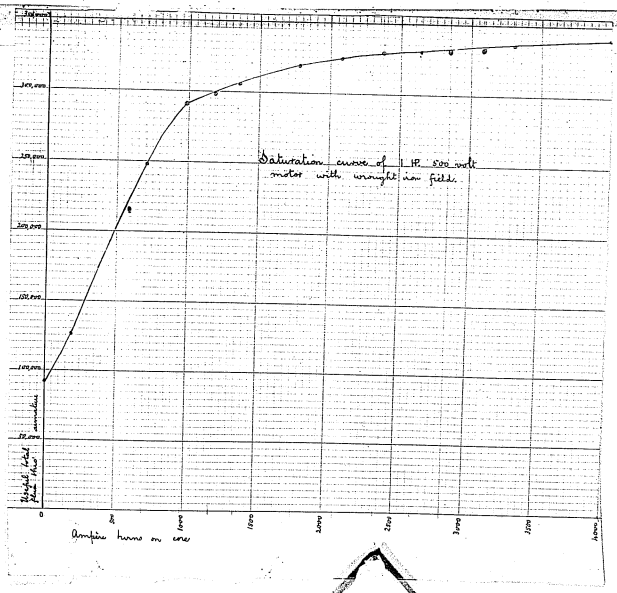
Effective area of piston dynamometer in Machine Shop.

The diam of the cylinder is 3⅞" = 3·9373" = 12·18 sq.in.

" " " " piston rod is ⅞" = 0·144 " "

Effective area 11·74 " "

A large angle plate weighing by scales 718 lbs gave 0·94" with a #60 spring in the old style Isbor indicator fitted to this piston, representing 56·4 lbs × 11·74 = 662 lbs or 92·2% of the true amount.


Saturation curve of 1 HP 500 volt motor with wrought iron field.
Amperes turns on one
Magnetic field flux per square inch
Total lines
0
2000
3000
4000

Test of 1 H.P. Edison Motor with wrought iron fields and 500-volt armature 24" by Samp. 20. (11)

With 3 amperes in the field circuit and 500 volts on motor, the armature made about 2100 r.p.m.

The motor in wrought iron fields weighs 79 lbs. with 4" pulley.

- diameter of the core is 2.5" (6.350m) wound to 3.95" (10) with #16 B.W.G. 0.065" cond: to 0.061". in 10 layers of 148 turns each. Mean diameter 3.25". mean circ: 10.21" = 0.85' × 4.80 turns = 4.0824 = 0.997 ω. The actual res: is 1.065 ω slightly warm. The spaces occupied by this winding is 4.15" (7.345) = 30.48 c.m. The weight of wire is 5.23 ℔ so that the wt per ℔ of wire is in this instance 5.83 c.m. allowing for paper insulation on core say 5.75 #/m.

The following is a test of the magnetic circuit of the machine:

Observ. in field wt.	Current in field wt.	Amp. turns in field wt.	Mmf in field wt.	Alternator Tangent in mm (1915)	Amps. in Armt.	Drop in armature (1915)	Emf generated (1915)	Revolutions of armature per min.	Revolutions of armature per sec.	ϕ arm.	$\mathfrak{B}$	ρ	Reluctance Steel
1.	1.718	8.958	4127	5187	0.330	0.256	5	117.5	407	6.78	343,700	17,185		3.418 K10
2.	1.598	8.306	3987	5012	-	-	-	-	411	6.85	340,300	17,015		3.453 -
3.	1.322.	6.898	3312	4163	-	-	-	-	417	6.95	335,400	16,770		3.503 -
4.	1.232	6.427	3085	3878	-	-	-	-	420	7.	333,300	16,680		3.522 -
5.	1.138	5.937	2850	3582	-	-	-	-	422	7.03	331,600	16,580		3.543 -
6.	1.052	5.488	2634	3311	-	-	-	-	424	7.07	329,700	16,485		3.564 -
7.	0.947	4.941	2372	2982	-	-	-	-	426	7.1	328,300	16,415		3.579 -
8.	0.827	4.315	2071	2603	-	-	-	-	431	7.18	324,700	16,235		3.619 -
9.	0.712	3.715	1783	2241	-	-	-	-	438	7.3	319,300	15,965		3.679 -
10.	0.585	2.844	1365	1716	-	-	-	-	458	7.63	305,500	15,275		3.846 -
11.	0.474	2.473	1187	1492	-	-	-	-	470	7.83	298,400	14,920		3.927 -
12.	0.395	2.061	989	1243	-	-	-	-	482	8.03	293,200	14,515	6.29 X10⁴	4.037 -
13.	0.282	1.471	706	888	0.339	0.263	5.1	117.4	563	9.4	248,000	14,400	.566 X10⁴	4.737 -
14.	0.213	1.111	533	733	0.334	0.275	5.4	117.1	670	11.16	216,500	10,825	5.92 X10⁴	5.425 -
15.	0.077	0.402	193	243	0.1932	0.382	7.5	115.0	1093	18.05	126,400	6320	7.23 X10⁴	9.098 -
16.	0.	0	0	0	1.918	0.924	18.0	104.5	1341	22.35	92,800	4,640		11.26 -

Res. of armature between brushes cool (19.5°)
5040 wire in armature.

Operating the machine with 500 volts at mt. the current in the field being 4.801 ℐ or 2304 a.t. the current taken by the armature = 0.444 ℐ (tan⁻¹ 3'20' = 0.1311) and the speed 1725 revs. The drop in the armature being 5.7 volts, 491.3 is the c.m.f. generated. the emf per rev. per sec. = 17.09, that is the preceding test 16.09 with 122 volts.

Allowing 750 Ahms, and 0.2 amp = 1875 turns in all, to have a resistance of 4 ohms. 1875 × 0.85 = 1594' for 4 ω = 400' per ω = 0.072 #15 B.W.G. 1600 × 0.01571 = 25 lbs. 1600' with 5.2 lbs = 307.6' per lb. #21 B.W.G. 1600 × 0.0715 = 114 ω. Allowing 500 Ahs and 0.2 amp = 1250 turns = 1063' weighing 5.5 lbs = 193' per lb. = #19 B.W.G. = 5.5 × 1.25 = 6.88 ω hot.

Tests of the Sprocket Belt on the Street Car Experimental Truck 26th Jan. 91.

This belt is made of Jute 1/2" thick + ∞ shape. It weighs 13 lbs. per foot and is 6" wide 19' long. It runs over a sprocket 16" in pitch diameter, and over two pulleys on the axles 24" diameter. One of these pulleys was faced with sheet lead 1/16" thick the other with blocks of oak. The car was in these tests raised off the truck, and the motor started, it was then lowered down to put work on the axles, and the pull from these horizontally was measured with a dynamometer.

No. of Obs.	Volts	Amps.	Watts	Speed motor	Speed of axles	Sag in Belt	Driving pulley.	Following pulley.	Dynamo. pulls.	Weight	Length of Tension in belt when in motion	Pull in lbs.
1	450	20	9000	240	36	—	Wooden	Leather	72 lbs	Tram motor	19'60"	1508
2	"	"	"	"	"	1/16"	"	" on back	780	"	19'60"	1508
3	"	"	"	"	"	1/8"	"	"	1200	"	19'6"	1380
4	"	"	"	"	"	1/4"	Leather	Wooden block	900	"	19'7"	1120
5	500	29	14,500	280	42	3/4"	"	"	1200	" + 72	19'7"	1120
6												

Constant of Ring Tangent Galvanometer after readjustment 27th Jan. 91

Obach 0.745 ± (3.588%) Ring 27.° 0' = tan 0.50953 = 0.1311 tan per amp.

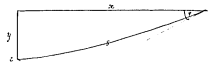
Calibration of Obach Galvanometer 27th January 1891.

This instrument was readjusted, and mounted with hole, slot and plane. It was then calibrated by copper electrolysis as follows

	Weights Before	of Plate After	Difference Grains	Loss grains	Accepted transfer grains	Time of test seconds	Transfer per second grains	Mean Current amperes (C.G.S. Units)	Number of each Reading	Mean Reading	Tans per 1 amp.
A	41·6565	42·2647	0·6082								
B	34·9693	34·2794		0·6899	0·6899	900	0·0007666	2·332	79	0·4472	0·1918

Test of the other Galvanometers

Instrument	Reading	Obach	amp.	Tans of Reading	Tan per amp.	Mean	H
Standard	47°·30'	0·164	0·8552	1·09131	1·276	1·278	0·1912
"	47°·20'	0·163	0·8501	1·08496	1·276		
"	59°·0	0·249	1·298	1·6643	1·282		
"	59°·20'	0·248	1·293	1·68643	1·304		
Ring	24°·30'	0·587	2·967	0·39391	0·1328	0·13275	
"	26°·10	0·710	3·703	0·49134	0·1327		
Sunnicrous	72°·40'	0·083	0·43328	3·2046 ep. root	0·7402	7·40	
Dynam. others	20°·4'	2·455	12·80	116·293	1·116	1·1165	
	15°·5'	2·16	12·26	12·570	1·025		



$$y = \frac{x^2}{2c}\left[1 + \frac{1}{12}\left(\frac{x}{c}\right)^2\right]$$

$$x = \sqrt{2cy}\left(1 - \frac{y}{12c}\right)$$

$$c = \frac{x^2}{2y} + \frac{y}{6}$$

$$\tan\gamma = \frac{2y}{x}\left[1 + \frac{1}{3}\left(\frac{y}{x}\right)^2\right]$$

$$s = x\left[1 + \frac{1}{6}\left(\frac{x}{c}\right)^2\right]$$

Problem — Having given the dimensions of the car wheels and truck shewn on p: 66, to determine what the catenary pressures will be on the two axles when 1600 lbs is delivered by each belt at the axle.

1st Assume that all the work is done by the leading wheel, lined with oak for which $\mu = 0.25$

In order to deliver a pull of p: lbs. weight at the axle, the difference of tensions must be αp when α is the ratio of the belt radius to the wheel radius.

$$\therefore p = \alpha(T_1 - T_2)$$

$$T_1 = \epsilon^{\mu\theta} T_2$$

$$\therefore p = \alpha T_2(\epsilon^{\mu\theta} - 1)$$

$$\text{or } T_2 = \frac{p}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$$T_1 = \frac{\epsilon^{\mu\theta} p}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$$T_1 + T_2 = \frac{p(\epsilon^{\mu\theta} + 1)}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$T_1 + T_2$ is the pull brought to bear on the axle journal.

$\alpha = 0.8 \quad \theta = \pi \quad \mu = 0.35 \quad p = 1600$

$$\therefore p = 0.8(T_1 - T_2)$$

$$1600 = 0.8\, T_2(\epsilon^{1.10} - 1)$$

$$T_2 = \frac{2000}{2.01} = 1000$$

$$T_1 + T_2 = \frac{2000(3.01 + 1)}{3.01 - 1}$$

$$= 2000 \times \frac{4}{2} = 4000 \text{ lbs. wt.}$$

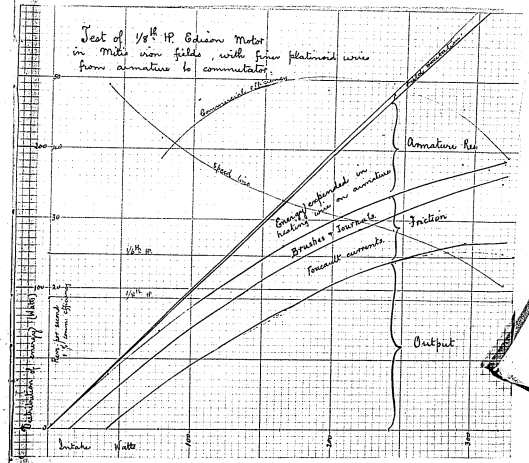
Abstract of a Report of the Pull required to start a car on level rails, by Mr John Krucsi, forwarded to the Engineer-in-Chief on the 29th January 1891

Conditions. Car placed on rail (4'8½"), a steel rope attached to the periphery of the wheel and a direct pull applied by means of weights. Diameter of wheel. 30". After each test the car was put back into the same position and the lap of the rope on the wheel kept the same, so that the tests were made under the same conditions and on the same part of the rails. The first test on the tractors of the car empty gave a result of 235 lbs. pull, but after the wheels had passed over the rail two or three times, this was decreased to the above figure (216).

Weight of car body 34405 lbs.
" " truck 3910 "
" " motor 4240 " 11,555 lbs

No. of test	Weight of car	Load added	Total weight lbs.	Pull required to move weight	Pull per ton of 2000 lbs	% of load in pull
1	11,555	–	11,555	216	37.4	1.87
2	11,555	2078	13,633	240	37.2	1.76
3	11,555	4121	15,676	260	33.2	1.66
4	11,555	8286	19,841	300	30.2	1.51

No. of Obs.	P.D. at motor terminals volts	Obsvd. Current in motor amperes	Current in field amperes	Ave. of armature	Drop in field volts	Energy in motor watts	Energy in field watts	Energy in armature watts	Drop in armature volts	E.M.F. of armature volts	Watts in armature
1	121.5	0.4655	0.339	1.0	15.0	0.312	41.2	0.115	41.1	5.09	116.1	1.8
2	121.0	0.432	0.6365	1.0	16.0	0.64	77	0.41	76.6	10.7	107.7	6.9
3	120.5	0.260	1.357	1.1	16.5	1.5	163.5	2.04	161.5	22.4	96.6	30.4
4	116.5	0.392	2.094	1.1	16.75	2.25	244.3	4.6	237.7	34.25	82.0	60.0
5	117.9	0.473	2.468	1.2	17.0	2.9	291	7.2	283.8	42.0	77.0	92.9
6	117.5	0.525	2.739	1.35	17.9	3.7	322	10.1	312.9	49.0	64.8	134.4
7	116.5	0.510	2.661	1.35	17.9	3.6	310	9.6	300.4	47.6	68.9	117.1



Test of 100-Watt Edison Motor after setting it in mitis iron fields, and using smaller platinoid wire between armature and commutator, also using grease tubes. 29th Jan. 91.

The res: of armature between diametrical brushes — cool = 17.75 Ω including platinoid
" " " " " — " = 14.95 "
" " " " " — hot = 16.
Inductance. " " " (in field unexcited) 394 h. res: 10.5 h. res: 0.95 and 12 Ω
" " field (armature in place) "

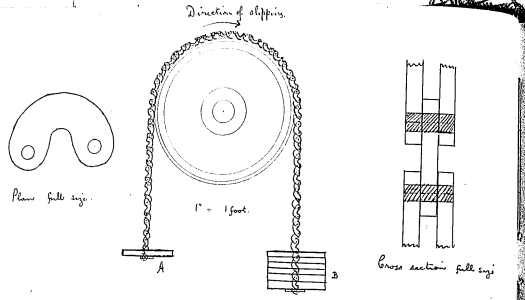
Motor floated and driving the ¾ H.P. Mitis iron dynamo sep: excited.

Watts in armature	Field R.p.m.	Field R.p.m.	Motor Self exciting (Carbon commut) Volts	Amps	Rly rpm	Rly ohms	Moment	Volts Moment	Delivery	Commut efficiency	Electrical efficiency	Effort at arm.	Friction	Conditions
1·8	2490	49·0	50	0	50	0	—	—	—	0	0	39·3	39·3	Running light
6·9	2490	41·5	50	0	50	23·1	115·5	$7·120 \times 10^6$	29·36	0·384		69·8	40·2	Driving arm: light
30·4	1975	32·9	50	0	500	19·5	1975	$2·451 \times 10^7$	81·62	0·699		131·1	49·5	Opposite S. Exc.
60·0	1715	28·6	50	0	500	36·2	6810	4·199	120·1	0·496		167·7	47·6	1 lamp
93·9	1490	24·9	50	0	500	24·4	8720	5·376	133·3	0·458		190	56·7	2 "
134·4	1240	20·7	50	0	500	27·5	9525	6·057	125·4	0·39		177·5	52·1	3 "
117·1	1235	20·7	"	"	"	"	"	"	"	0·39		183·3	57·9	after 1 hour

The temp of the field was 95° F after 2 hours run.

The maximum commercial efficiency of the motor, when tested on the 8th Jan: in the wrought iron fields was 0.38. The mechanical friction is probably the same but the electrical friction appears to have been materially reduced. The total friction is now from 40 to 55 Watts. On the 8th of January it was from 70 to 90 Watts.

The pole pieces are the same, and the armature is the same except that the platinoid wire has been reduced from 0.011" to 0.0073"



Measurement of some coefficients of friction

20th January 1831

An iron pulley, faced (10 2/12" diam.) with the substance tested was fixed with its axle horizontal. A chain, (and in the case of rubber also a strip of iron formed of 1/4 links, length 9/16". There are 9/4 links one to end, each 1" pitch. The links are of the dimensions shewn on the opposite page. The weight of this length of chain was 10 lbs., and with a shoe at each end 13. In almost all the tests a fixed weight was supported at one end and weights added to the other end until slipping commenced or could be maintained. The angle of embrace was π.

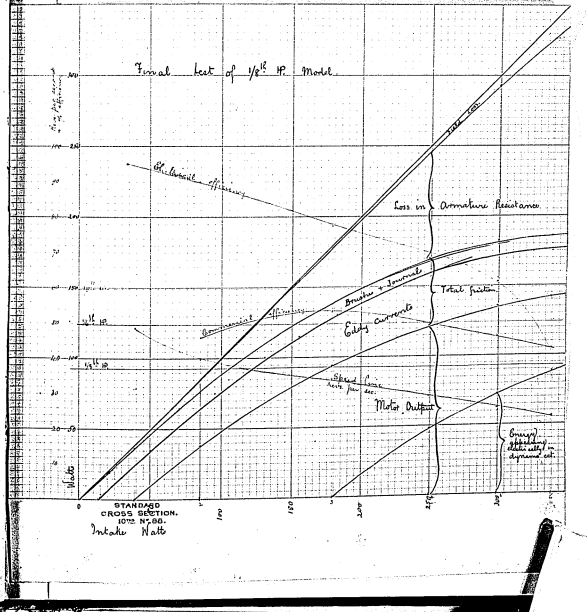
These results are tabulated allowing 3 lbs on each side for chain-weight and assuming no weight in the length of chain resting on the pulley.

No. of Obs.	Chain	Diam. of pulley	Material	Condition	Total Weight A lbs.	Total Weight B lbs.	ratio B/A	$\mu\theta$	μ	character
1	Link	24 7/16"	½" leather face	normal	3 3/4 lbs	8 5·5	2·673	0·9821	0·31	sliding
2				wetted	"	5 8	1·813	0·5933	0·19	"
3				wet sand	"	12 0	3·938	1·3712	0·444	"
4				oiled	"	6 4	2·00	0·6931	0·22	"
5	Link	24 7/16"	Wooden	normal	"	6 4	2·00	0·6931	0·22	"
6	"			wetted	"	10 4	3·25	1·1787	0·38	stationary
7	"			"	"	7 4	2·313	0·8372	0·27	moving
8	"			wet sand	"	10 0	3·125	1·1411	0·36	stationary
9	"			oiled	"	6 4	2·0	0·6931	0·22	moving
10	"			"	"	12 3	3·845	1·3461	0·43	stationary
11	"	25 ½"	½" rubber	normal	"	29 3	9·16	2·2148	0·71	"
12	steel band	"	"	"	7 lbs.	5 3·5	7·644	2·0334	0·65	moving
13	"	"	"	wetted	"	"	"	2·0334	0·65	"
14	"	"	"	oiled	8·25	26·5	3·212	1·1663	0·37	"

The wooden pulley had its face formed of oak blocks with the grain radial. The rubber pulley had its face coated with ½" thick continuous rubber not pure gum but lightly vulcanized. The steel band used in the last experiment was 0.007" thick and 1½" wide.

Material	no	Material	Starting μ	Moving μ
Iron chain	1	lead dry	0·35	0·31
	2	do: wet	0·25	0·19
	3	do wet sanded	0·50	0·444
	4	do oiled	0·25	0·22
	5	oak across the grain	0·25	0·22
	6	do. wet	0·38	0·27
	7	" wet sanded	0·38	0·36
	8	" oiled	0·43	0·22
	9	rubber normal	0·71	0·71
steel band	10	" "	0·65	0·65
	11	" wetted	0·65	0·65
	12	" oiled	0·37	0·37

No. of Obs.	P.D. in mains beyond coil	Observed	Current flow in mains amperes	Energy in mains watts	Rev. per min.	Drop in field volts	Energy in field watts	p.d. in armature volts	energy in armature watts	rev. of armature	Drop in armature volts	Energy lost in armature watts	e.m.f. generated volts	Energy converted into	Speed r.p.m.	r.p.s.
1	121.5	0.061	0.318	38.6	1.0	0.3	0.1	121.2	38.5	16.5	5.25	1.67	115.9	36.8	2900	48.37
2	"	0.132	0.639	83.7	.	0.7	0.5	122.8	83.2	16.75	11.5	7.9	109.3	75.3	2395	39.92
3	120	0.285	1.497	178.2	.	1.5	2.2	118.5	176.2	17.0	25.3	37.6	93.2	138.6	2025	33.75
4	120	0.396	2.066	248.0	.	2.1	4.3	117.9	243.7	17.5	36.25	74.8	81.7	168.9	1705	28.42
5	121.25	0.472	2.463	298.6	1.1	2.7	6.7	114.6	293.9	18.0	44.3	109.1	70.3	182.8	1510	25.18
6	121.75	0.534	2.786	339.2	1.2	3.3	9.3	112.5	329.9	18.5	51.5	143.5	61.0	186.4	1348	22.47
7	119.5	0.587	2.97	352.8	1.3	3.9	11.5	108.0	343.3	19.0	56.4	167.5	52.6	175.8	1218	20.3
8																



Test of the ½ H.P. motor after changing the platinoid wire a second time in order to reduce sparking.

The only change in the motor since the last recorded on page 80 has been in the platinoid wires which have been reduced to a diameter of 0.0056" with a resistance of 1.14 ω each.

Motor self exciting, mounted in boat.

Field I amps.	Total Cir. gen. I amps.	Mean Volts	Output watts	Elect. η	Mech. η	Voltage across brushes	Field at brushes Gauss	Amps. in armature	Amps. shunt in armature	E.M.F. generated	Speed Radians per second	Motor Horse power	
0	(933)			0.953	0	3.66							
5	39.92	50 a 31.2	1560	not 0.960	38.4	0.90	0.489	2.874					36.8	Light.
5	33.72	from 10 to 0	44.345	2.802	94.6	0.777	0.530	2.76					36.9	complete
5	26.2	from 15 to 0	7000	4.316	122.7	0.681	0.495	2.88	113.25	0.05332	0.4417	1.824	115.1	48	46.2	1 Lamp.
0	25.7	from 0 to 20	8765	5.604	136.	0.612	0.456	2.79	100	0.09335	0.703	3.09	103.1	72.5	44.8	2 Lamps
8	22.2	from 0 to 25	10,300	6.351	142.7	0.621	0.421	2.72	90	0.12574	0.947	4.17	94.2	89.2	43.7	3 Lamps
7	20.3	from 0 to 28	11,100	6.842	138.9	0.592	0.392	2.514	-	0.13461	1.0114	4.446	-	-	36.9	4 Lamps

Particulars of the completed motor.

Weight without wooden base 19½ lbs.
- with - - 21 -
- of armature 4½ lbs.

Diameter of core 1.4" } Mean diam. 1.86" over wire
- over wire 2.28" } - - 1.862"
- outside covering

Resistance of field winding 0.955Ω @ 18°C.
Length 222'
Weight 1.62 lbs.
Turns 480

Res. of armature between brushes (cool) 16.0Ω
17.75Ω hot

The inductance of the armature 394 H between brushes
- - - one coil on . . 9.2 - field off
- - - - - - 6.7 - - on undrilled
- - - - - - 2.0 - - between pole

Res. of one coil of the armature 1.33Ω cool
1.5Ω hot

Length of platinoid wire 3½"
diameter - - 0.0056"
res. - - 1.14Ω

If the friction on the rubber were independent of the velocity the motion would be accelerated. It is not accelerated, therefore the friction is a function of the velocity, and the equation of motion is of the form $m\frac{dv}{dt} = f - \varphi(v)$

The form of the function $\varphi(v)$ is not known, but the results observed are capable of being represented (to a first approximation) by one of two hypotheses viz that $\varphi(v) = \alpha v$

2nd $\varphi(v) = \beta(v^2)$

Consider the 1st hypothesis

$$m\frac{dv}{dt} = f - \alpha v \qquad \text{Let } f = \alpha(V)$$

$$\text{Then } m\frac{dv}{dt} = \alpha(V - v)$$

$$\text{or } dt = \frac{m}{\alpha}\left(\frac{dv}{V-v}\right)$$

$$t = -\frac{m}{\alpha}\log_e\left(\frac{V-v}{V}\right)$$

$$\frac{V-v}{V} = e^{-\frac{\alpha t}{m}}$$

$$v = V\left(1 - e^{-\frac{\alpha t}{m}}\right)$$

$$= \frac{f}{\alpha}\left(1 - e^{-\frac{\alpha t}{m}}\right)$$

On the 2nd hypothesis $m\frac{dv}{dt} = f - \beta v^2 \qquad \text{Let } f = \beta V^2$

$$\text{Then } m\frac{dv}{dt} = \beta(V^2 - v^2)$$

$$dt = \frac{m}{\beta}\frac{dv}{2V}\left(\frac{1}{V+v} + \frac{1}{V-v}\right)$$

$$t = \frac{m}{2\beta V}\log_e\left(\frac{V+v}{V-v}\right)$$

$$\frac{V+v}{V-v} = e^{\frac{2\beta V t}{m}}$$

$$v = V\frac{e^{\frac{2\beta V t}{m}} - e^{-\frac{2\beta V t}{m}}}{e^{\frac{2\beta V t}{m}} + e^{-\frac{2\beta V t}{m}}} = V\tanh.\frac{2\beta V t}{m}$$

$$= \sqrt{\frac{f}{\beta}}\tanh.\frac{2\beta V t}{m}$$

On the first hypothesis, the time required to generate ~~the~~ half the limiting velocity is $t_{\frac{1}{2}} = -\frac{m}{\alpha}\log_e 0.5 = 0.694\,\frac{m}{\alpha}$

On the second hypothesis $t_{\frac{1}{2}} = \frac{m}{2\beta V}\log_e 3 = \frac{1.099}{2}\,\frac{m}{\beta V} = 0.55\,\frac{m}{\beta V}$

Such acceleration as exists is apparently practically over in one second so that 0.5 sec is more limit of $t_{\frac{1}{2}}$ so that on either hypothesis α or β have large magnitude.

(83)

Experiments on the frictional resistance of vulcanised rubber to motion over its surface. 31st Jan. 91.

The rubber band pulley 200 cms in circumference adopted to on page 81 was again used for this experiment. Its was clamped to its axle which was horizontal. The steel board of length 183 breadth 4.15 and 0.01 thickness (0.01 (cms) weighing 514 gms already described on p. 81 was laid over the pulley at right angles to the axis, and a wire weighing 446 3.4 gms (11 + 2.4 + 50 gms) was attached to one end, and by means of a similar wire, a total weight of 3317 gms in the 1st and 4763 gms in the second tests were respectively suspended at the other end. A steel metre tape was wound once round the pulley about 1 cm distant from the slipping tape and by means of a watch the time that a mark on the slipping tape occupied in passing certain distances on the metre tape was observed.

No. of Obs.	Total Distance round cms.	Time of contact Pulley & tape Secs.	Error per second	Mean per cm.	Total dist. round cms.	Total time from start Secs.	Mean per cm.		Total dist. round cms.	Total time from start Secs.	Mean per cm.	Total dist. round cms.	Total time from start Secs.	Mean per cm.
					Set # 1 with 3317 gms						Set # 2 with 4763 gms			
1	0·9	15			0·5	2.2	44	1 + 19	1·	·9	9	19	151·5	7·5
2	1·5	30		33	1·	3·9	34	2 + 20	2·	1·6	7	20	158	6·5
3	1·8	45		23	·5	5·7	36	3 + 21	3	2·5	9	21	167	9
4	2·45	60		2·	7·5	36	4 + 22	4	3·2	7	22	176	9
5	3·00	74		25	·5	9·5	40	5 + 23	5	3·9	7	23	185	9
6	4·0	98		24	3·	11·4	38	6 + 24	6	4·7	8	24	194	9
7	4·5	112		28	·5	13·1	34	7 + 25	7	5·5	8	25	201	7
8	5·0	123		22	4·	14·8	34	8 + 26	8	6·3	8	26	211	10
9	·5	132		18	·5	16·2	36	9 + 27	9	7·2	9	27	220	9
10	6·	145		26	5·	17·8	32	10 + 28	10	8·0	8	28	228	8
11	·5	157		24	·5	19·1	26	11 + 29	11	8·8	8	29	237	9
12	7·	169		24	6·	20·6	30	12 + 30	12	9·4	6	30	247	10
13	·5	183		28	·5	21·8	24	13 + 31	13	10·2	8	31	255	8
14	8·	198		30	7·	23·3	30	14 + 32	14	11·0	8	32	265	10
15	·5	213		30	·5	24·9	32	15 + 33	15	11·9	9	33	273	8
16	9·	228		30	8·	26·7	36	16 + 34	16	12·7	8	34	283	10
17	·5	244		32	·5	28·5	36	17 + 35	17	13·5	8	35	292	9
18	10·	260		32	9·	30·5	40	18 + 36	18	14·4	9			
19	·5	278		36	·5	32·6	38							
20	11·	295		34	10·	34·2	36							
21	·5	313		36	·5	35·9	34							
22	12·	332		38	11·0	37·7	36							
23	·5	348		32	·5	39·2	30							
24					12·	40·8	32							
	Mean			28	·5	42·5	34					Mean		8·35

Mean 34 secs per cm.

M phr. ft/sec cm/sec.

Snail

Rivers ¶

Man walking from amateur recs 8·1776 / 8 1/3 / 1/4 — 11.985

Man swimming (from amateurs records) 120 yds in 1 1/4 min / 360 feet - 99·5 cm — 4.022

Int. International Boat Races

✓ Man skating 1/4 mile + 1/320 in 35 secs — 37.71

✓ Man running 100 yds / 300 in 9.8 secs. — 30.61

Man bicycling 1/2 mile / 1320 in 25 secs. — 52.80

Horse galloping (racing records) 1·5 m / 5280 in 253 — 51.77

✓ Horse trotting — — 1 m / 5280 in 2·032 / 123 — 42.93

Railroad fastest record. 112·5

Swallows' flight 4000

Projectiles 44 000

Sound 33,550

Meteors 180,000

1800

30 180,000 ft. per hr

3000

50

112·5 × 22 / 15

5280 / 264000

101·5 / 13000 / 3600

·03

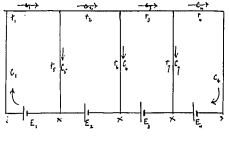
Table of Velocities. Febry. 1891 (22)

		miles per hr	ft per sec	cms. per sec.
Railroad	train	60		2700
Swallows	flight	67 - 92		3000 - 4000
Projectiles		672 - 920		3.4×10^4 - 4.4×10^4
Sound		750		33,550
Mercury's	Movement in her orbit	109,358		4.93×10^6
Venus'	- - - -	83,162		$3.678 \times$ -
Earth's	- - - -	68,052		$3.04 \times$ -
Mars	- - -	55,135		$2.46 \times$ -
Light				3.0×10^{10}
Meteors	encountering earth's atmosphere lowest	7,200		
	highest	180,000		

$c_3 = c_2 - c_1$

$c_6 = c_5 - c_3$

$c_7 = c_6 - c_5$



$c_1 r_1 - c_2 r_5 = E_1$

$c_2 r_6 + c_3 r_5 \mp c_4 r_7 = E_2$

$c_3 r_3 + c_4 r_7 - c_5 r_4 = E_3$

$c_5 r_4 - c_6 r_7 = E_4$

Standard Determinant for use in Calculating pressures and currents in Edison 5-wire systems

c_1	c_2	c_3	c_4	=	
$r_1 + r_5$	$-r_5$	0	0	=	E_1
$-r_5$	$r_6 + r_5 + r_7$	$-r_6$	0	=	E_2
0	$-r_6$	$r_3 + r_6 + r_7$	$-r_7$	=	E_3
0	0	$-r_7$	$r_4 + r_7$	=	E_4

(85)

Characteristic curve of 2 1/8 H.P. mitis-ion completed model.

Feb 21 1891

Field separately excited. For plotted curve see next page.

No. of Obs.	Counts in Volts	Watch	Amperes	Amperes (Calibrated)	MMF	Volts at mot.	Standard Tacho	Amperes	Disp. Flow	E.M.F	Speed R.p.m.
1	18	1·15	5·997	2699	3390	121·5	0·274	0·214	3·4	64,890	118·1	2000
2	12	0·915	4·772	2148	2700					61,320		2050
3	9	0·732	3·817	1718	2160					62,400		2080
4	7	0·582	3·035	1366	1720					61,020		2125
5	6	0·503	2·623	1181	1485					60,370		2150
6	5	0·422	2·201	990	1245					59,800		2170
7	4	0·349	1·820	819	1030		0·293	0·229	3·7	58,230	117·8	2215
8	3	0·265	1·382	622	782		0·296	0·232	3·7	59,200		2300
9	2	0·182	0·949	427	537		0·385	0·239	3·8	59,150	117·7	2395
10	1	0·098	0·511	230	289		0·335	0·262	4·2	63,990	117·3	2680
11	0	-	-	-	-		0·669	0·524	8·4	35,350	113·1	3200

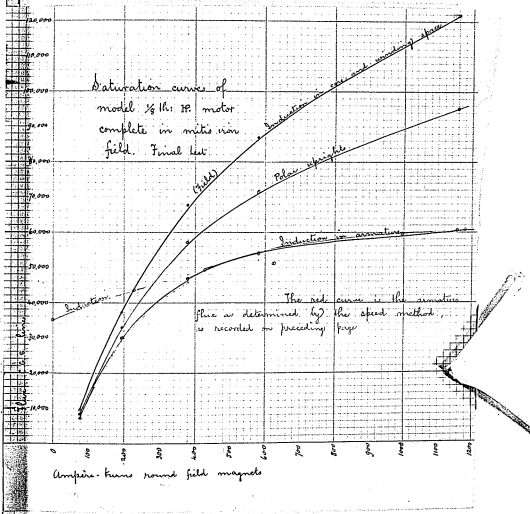
The machine comes to rest from 2900 revs: in 76 secs: after opening circuit. The mass being 1960 gms. and the radius of gyration $\frac{11}{2}$ cms, the moment of inertia = $2{\cdot}372 \times 10^5$ cm²-gms. The angular velocity = 58000 π at about full speed = $\frac{18220}{60}$ π radians per second. The angular acceleration is $-\frac{2400}{60}$ radians per sec: per sec: so that the moment of friction is $\frac{5{\cdot}60}{\pi} \times \frac{10^7}{60}$ dyne-cms. The energy at full speed is $\frac{2{\cdot}372}{8} \times 10^{12} \times (1{\cdot}823)^2 \times (60)^2$ $\frac{9{\cdot}837 \times 10^{12}}{3{\cdot}6 \times 10^{12}}$ ergs per sec. per sec. (exp) = $\frac{9{\cdot}837 \times 10^{12}}{3{\cdot}6 \times 10^{12}}$ Joules = $2{\cdot}73 \times 10^6$ Joules

Moment of friction $2{\cdot}371 \times 10^5$ dyne cms.

$4{\cdot}312 \times 10^4$ dynes at rad: of Gyration

Kinetic Energy of rotation 273 Joules light

130 " at full load.


Saturation curves of
model ½ Hp. motor
complete in mitis iron
field. Final test.
Induction in iron ring mounting of pole
(yoke)
Pole piece
Induction in armature
Induction
The red curve in the armature
flux as determined by the speed method
is recorded on preceding page
Ampère-turns round field magnets

Magnetic Circuit Test of Completed 1/8 h.p. Motor.

2. 2 91.

Five turns of wire were wrapped round (1) the magnet unit center
(2) - four polar keep
(3) - top of the armature between pole
(4) - bottom - - pole

and the throws on reversing the current through the field magnet observed on ballistic galvanometer with the following results :—

The front side of the motor is the commutator side.

No. of Obs	Source of EMF	EMF	Coeff	q.	Mean throw	q. per div.
15	1 B.C. @ 11°C.	1.438	1 P	1.438×10^{-7}	115.8	1.242×10^{-9}

No. of Obs	Observ	Amps	Amp. Turns	MMF.	Mean flux	R. of q.	q	Φ	Σ	2ϕ	mean
1	0.032	0.1669	75.1	94.4	.15	5250		97,800	990		
2	0.0825	0.4302	193.6	243.3	57.1			372,300	3760		
3	0.1615	0.8422	379	476.3	103.7			67,600	10,830		
4	0.248	1.293	581.9	731.5	133			86,720	8,764		
5	0.492	2.566	1155	1452	187			121,900	12,320		
6	0.032	0.1669	75.1	94.4	6			3,910	870		
7	0.0825	0.4302	193.6	243.3	24			15,650	3480		
8	0.1615	0.8422	379	476.3	42			27,380	6090		
9	0.248	1.293	581.9	731.5	52.8			34,430	7650		
10	0.492	2.566	1155	1452	72			46,950	10,430		
11	0.032	0.1669	75.1	94.4	65			4,240	940	8,150	
12	0.0825	0.4302	193.6	243.3	262			17,100	3800	32,760	
13	0.1615	0.8422	379	476.3	344			29,150	64.80	56,520	
14	0.248	1.293	581.9	731.5	57			37,170	8260	71,600	
15	0.492	2.566	1155	1452	757			49,360	10,970	96,310	
16	0.032	0.1669	75.1	94.4	5.7			3,720	830		
17	0.0825	0.4302	193.6	243.3	21.8			14,200	3160		
18	0.1615	0.8422	379	476.3	38.8			25,300	5620		
19	0.248	1.293	581.9	731.5	49			31,950	7100		
20	0.492	2.566	1155	1452	66.7			43,500	9670		
21	0.032	0.1669	75.1	94.4	7			4,560	1010	5,280	5,220
22	0.0825	0.4302	193.6	243.3	28.5			18,580	4130	32,780	32,760
23	0.1615	0.8422	379	476.3	49.8			32,470	7220	57,770	57,150
24	0.248	1.293	581.9	731.5	61			39,780	8840	71,730	71,670
25	0.492	2.566	1155	1452	77			50,200	11,160	93,700	95,000
26	0.032	0.1669	75.1	94.4	5			3,260	1500		
27	0.0825	0.4302	193.6	243.3	23			15,000	6,880		
28	0.1615	0.8422	379	476.3	36			23,470	10770		
29	0.248	1.293	581.9	731.5	42			27,390	12,570		
30	0.492	2.566	1155	1452	46.8			30,520	14,000		
31	0.032	0.1669	75.1	94.4	6			3,910	1790	7,170	
32	0.0825	0.4302	193.6	243.3	23			15,000	6,880	34,000	
33	0.1615	0.8422	379	476.3	35.7			23,280	10,700	46,750	
34	0.248	1.293	581.9	731.5	40.8			26,610	12,210	54,900	
35	0.492	2.566	1155	1452	45.7			29,800	13,670	60,320	

First test of 120-volt 1 H.P. Motor 3rd Febry. 91.

The motor complete without base weighs 78·5 lbs. At 120 volts it runs at 1700 revs. p.m. With copper gauze brushes connecting three and occasionally four bars, the current absorbed in the armature with exp. coil field was 6 amperes. On replacing the brushes with brass gauze covering only two bars, this current fell to 5 amperes (600 watts). The diameter of the present size of wire from the commutator to the armature is 0·033". It is now proposed to employ 0·016" instead. The resistances per section is 0·1ω and of the armatures moderately warm, across one diam: 1·1ω including platinoid. Res: per section 0·2ω including platinoid. 9 layers of 11 turns

Measurement of the resistivity of some samples of platinoid.

A few short lengths were cut off three coils of the wire, laid upon a porcelain scale and measured by bridge as follows:—

Ref. No.	Diameter in cms.	Diameter in cms.	Area sq. cms.	Length	Res: read by bridge	Leads	Res: of wire, incl. leads ω	Res: per cm.	Resistivity @ 20°C.	Mean Resistivity @20°C.	Res: per foot	Mean Resistivity @0°C.	Means @ 0°C
1	0·003	0·02616	0·00053	100	7·1655	0·037	7·1285	7·1285×10⁻²	3·832×10⁻⁵				
2				80	5·7044		5·707	7·138 "	3·837 "				
3				60	4·315		4·278	7·130 "	3·833				
4	0·0390	0·07366	0·00242	100	0·961		0·924	9·24×10⁻³	3·938 "				
5				80	0·781		0·744	9·3 "	3·962 "	3·958×10⁻⁵	2·8934ω	3·913×10⁻⁵	3·898×10⁻⁵
6				60	0·596		0·559	9·317 "	3·971 "				
7	0·0142	0·03606	0·00102	100	3·794		3·757	3·757×10⁻²	3·837 "				
8				80	3·051		3·014	3·767 "	3·847 "	3·847×10⁻⁵	1·1407ω		
9				60	2·303		2·266	3·777 "	3·857 "				

Second test of 120-volt 1 H.P. motor 3. II 91.

The platinoid wire being now 0·016" in diameter. The resistances of a single section including platinoid is 0·6ω (0·25ω each pole pin) and the res: across amp: diameter 1·53ω. The current is 4 amp (500 watts). The poles become hot.

Rough Calculation of the power required to deposit 15 tons of copper daily from the digest of 100 tons copper ore.

The counter emf using carbon and copper in a solution of 1·15 $CuSO_4$ is 1 volt. One lb: of copper takes 381 amp:-hrs. say 400. 15 tons = 30,000 lbs = 12,000,000 amperes at 2 volts = 24,000,000 Watts daily = 1000 kilowatts continuously. (500,000 emf) The source of power is distant 1·5 miles.

The surface of cathode per ton in commercial refineries varies from 4,000 to 32,000 sq: ft:

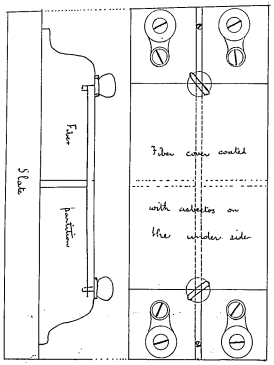
Test of High-Tension Safety Catch Cut Out.

4th February 1891.

Received a cut-out from the Engineering department, represented half size on the opposite page. A slate base 1" thick carries a pair of fibre partitions intersecting at right angles. Long fuses rest across these and these partitions serve to break the arc and keep the opposite pole apart.

Lead wire 0·065" in diam. ( ) was found to carry $\frac{2}{3}$ths of one ampere (impulse current) for two 7" lengths of these were inserted in the apparatus and the Municipal machine at about 1200 volts p.d. short circuited through it. The cut-out acted efficiently.

Two of these on each side were then tried on 600 volts a.k., and three of them on 500 volts with 65 amperes also o.k. The only objection is the possibility of throwing out melting lead on all sides, which under particular conditions might give rise to a conflagration. The machine should therefore be placed in a box.



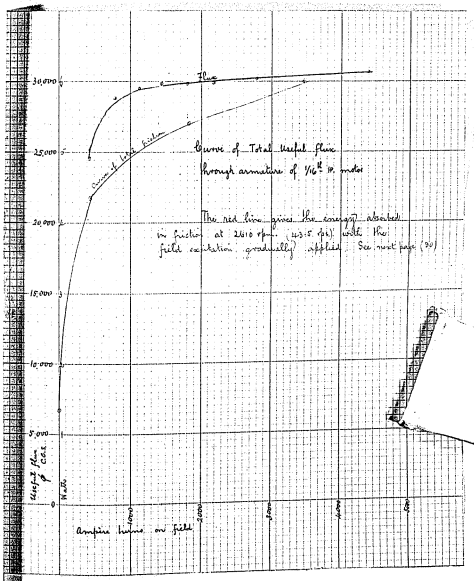
Inductance of large Wiedemann thermo-galv: coil

No. of Obs	Bridge Ratio	Resistance	Lead. + res:	Res: of coil	T.B. + coil	K.B.D.	coil to base line	Inductance	Coil marked	Coil no	Res: 0°C.	
1	100/1	12·907	10·434Ω	0·4731Ω	18·7°C.	1·762×10⁻⁶	1·748×10⁻⁶ H.	0·338	0·423	0·411		
2		12·909	10·473	0·427	18·9°C	1·665×10⁻⁶	1·650×10⁻⁶	1·480 H.	0·429	0·406	0·398Ω	

Test of 1 HP. 120-volt motor 4th Febry. 1891.

In order to determine the origin of the waste power in this motor the machine was set in the large bank and driven by the Edison 1000-watt motor. The armature was not allowed to take any current, and collector pulp were set over the commutator.

Test Obs	Speed of motor r.p.m.	Speed of motor r.p.s.	Scale	Reading	Moment	6165 × Moment ×10⁷	Energy absorbed W=2πn	Lamps in full use	Shunts	Ampères	Amp²-turns 6916
1	1635	27·22	250	@ 9·5	1875	1·156	31	0	–	0	0
2	1590	26·5	–	@ 22	5500	3·391	90	1	0·085	0·443	307
3	1590	–	–	@ 41·5	10375	6·398	170	2	0·158	0·824	572
4	–	–	–	@ 68	17000	10·48	278	4	0·310	1·616	1120
5	–	–	–	@ 79	19,750	12·18	323	6	0·495	2·580	1790
6	–	–	–	@ 86	21,500	13·26	351	8	0·620	3·232	1574
7	–	–	–	@ 89	22,250	13·72	364	14	0·928	4·838	3357
		The armature wire was cut in one place and the series repeated.									
8	1660	27·66	250	@ 7	1750	1·079	29·8	0	–	0	0
9	1640	27·22	–	@ 12	3000	1·850	49	1	0·090	0·469	326
10	H –	–	–	@ 20	5000	3·083	82	2	0·180	0·938	651
11	–	–	–	@ 42	10,500	6·472	172	4	0·320	1·668	1158
12	–	–	–	@ 68	17,000	10·48	278	6	0·460	2·398	1664
13	–	–	–	@ 71	17,750	10·94	290	8	0·593	3·092	2146
14	–	–	–	@ 81	20,250	12·48	331	10	1·069	5·570	3866


30,000
25,000
20,000
15,000
10,000
5,000
0
Useful flux
in C.G.S.
Watts
Amperes turns on field
Curve of Total useful flux
through armature of 1/16 H.P. motor
The red line gives the energy absorbed
in friction at 2610 r.p.m. (43·5 r.p.s.) with the
field excitation gradually applied. See next page (70)

Measurement of the resistivity of some samples of German Silver. 5th February 1891.

Took four samples of g.s. covered wire out of the stock-room and measured their resistances on the porcelain metre as follows—

Ref No.	Diam. of wire	Cross	Area	Length	Res. observed	Leads.	Res. of wire	Res. per cm.	Resistivity at 0°C	Resistivity at 18°C	Res. per foot
1				100	1·331	0·0515	1·2795	$1·2795 \times 10^{-2}$	$2·593 \times 10^{-5}$		
2	0·020"	0·0508	0·002027	80	1·080		1·0285	1·2859	2·606		0·313
3				60	0·898		0·8465	1·411 ?	–		
4				100	0·4355		0·3826	$3·826 \times 10^{-3}$	$3·563 \times 10^{-5}$		
5	0·0925	0·1087	0·009281	80	0·3610		0·3125	3·906 "	3·625 "		0·119 "
6				62·5	0·298		0·2465	3·945 "	3·662 "		
7				100	1·010		0·9885	$9·885 \times 10^{-3}$	3·1612 "		
8	0·0241"	0·0663	0·0031452	80	0·8118		0·7965	995 "	3·1816 "		
9				60	0·676		0·6245	10·41 "	3·593 "	$\frac{1}{3} \times 3·494$	0·303 "
10				100	1·723		1·6715	$1·6715 \times 10^{-2}$	3·128 "	$\times 10^{-5}$	
11	0·0201"	0·0511	0·002051	80	1·391		1·3395	1·6744 "	3·135 "	$\frac{1}{3} \times 3·1168$	
12				60	1·064		1·0125	1·6875 "	3·161 "		0·510 "
13				100	6·856		6·8045	$6·8045 \times 10^{-2}$	3·448 "		
14	0·010	0·0254	0·000507	80	5·502		5·4505	6·8131 "	3·423 "		2·076
15				60	4·102		4·0905	6·8175 "	3·424 "		

First Test of ⅙ HP. Motor 6th Feby

Field winding) 114 layers of 66 turns = 9224 turns #19 B.W.G. D.C.C.
" " Resistance cool = 2·38 ω @ 18°C
" Inductance (armature in place + feeble testing current) = 345 h.
Armature winding) across brushes = 14·393 ω @ 15°C
Weight 1335 gm. Inductance (in field) = 93·58 h. Field unexcited
= 74·9 h. " excited
Resistance of one coil including plug (Shunted by rest of arm.) = 3·9 ω @ 18°C.
Inductance " = 3·235 h. unexc. field
= 2·17 h under exc. pole piece
= 0·75 h between poles.

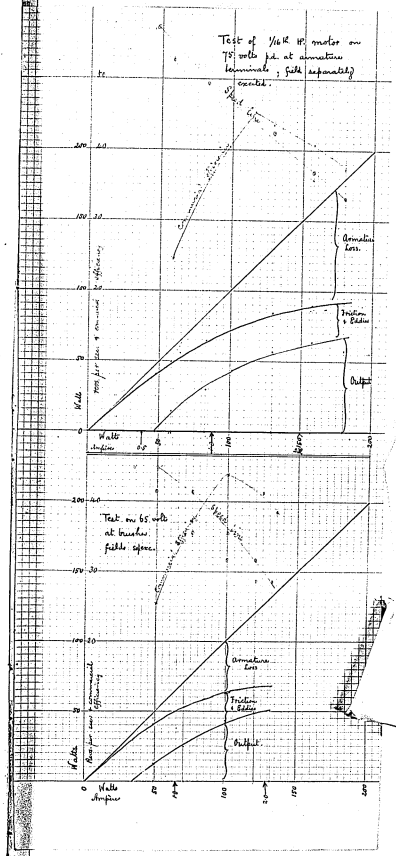
Tests 7th Feby Motor running light with exc. field on 65 volt ckt.

Voltage at brush	Current in field	Resistance	Amps.	Amp-turns	MMF	R.p.m.	Speed R.p.s.	Obsvd. time	Current in armature	Drop in armature volts	EMF generated volts	EMF per amp-turn volts	4πBA ϕ
12	0·8209	4·750	4389	5517	2327	38·8	0·126	0·637	9·53	49·5	1·276	30,690	
8	0·8976	3·004	2776	3490	21120	40·3	0·110	0·574	8·3	50·7	1·258	30,260	
6	0·31370	2·363	2183	2744	20640	40·7	0·180				1·246	29,970	
5	0·25862	1·947	1799	2262	21447	40·8	"	"	"	"	1·243	29,900	
4	0·20800	1·566	14447	1819	21480	40·8	"	"	"	"	1·243	29,900	
3	0·16296	1·227	1134	1425	21480	41·3	"	"	"	"	1·229	29,540	
2	0·11394	0·858	793	997	25140	42·3	"	"	"	"	1·199	28,840	
1	0·06116	0·461	426	536	28140	44·3	0·174	0·73	10·6	48·14	1·023	24,600	
0	–	–	–	–	–	–	–	–	–	–	–	–	plus 2·18 m.f.

With the current cut off the field, the speed at first reached about 3500 r.p.m. (Plus armature) declined, stopped and recommenced in the opposite direction.

Field of motor + abs of dynamo separately excited

No. of tbs	P.D. at brs	Watch fan.	Ampère in armr.	Energy in watts	Current thro' field	Resist. in field	Drop in armr.	E.M.F. generated by armr.	Loss of energy in armr.
1	60	0·110	0·574	34·4	1·260	1464	8·6	51·4	4·9
2	65·6	0·145	0·756	49·6			11·3	54·3	5·5
3	64·2	0·210	1·095	70·3			16·4	47·8	18·0
4	64·2	0·296	1·544	99·1			23·2	41·0	35·8
5	64	0·360	1·877	120·1			28·2	35·8	52·9
6	63·1	0·400	2·086	131·7			31·3	31·8	65·4
7	74	0·465	2·425	179·4			36·4	37·6	88·2
8	74·2	0·405	2·112	156·7			31·7	42·5	66·9
9	74·5	0·333	1·737	129·4			26·1	48·4	45·3
10	75	0·21	1·095	82·1			16·4	58·6	17·9
11	75	0·15	0·782	58⅝			11·7	63·3	9·2
12	75	0·12	0·626	47·0			9·4	65·6	6·0
13									



Test of 1/16 H.P. (50 Watt) Motor 7.II.91

Motor balanced in lamb and driven by a 1/2 H.P. D.C., with usual connection. The friction was observed with the field varied and removed as follows:

	Speed r.p.m.	n.p.s.	Ring: Ism amp.	0.1358	Amp: Ism amp.	Balance gms.	Moment	6165 × moment	Energy absorbed
1	2610	43.5	0	0		1	50	3.33 × 10⁶	1.34
2	"	"	0.06554	0.4914	456	3.2	160	9.866	4.3
3	"	"	0.12279	0.925	855	"	"	"	"
4	"	"	0.17633	1.328	1227	"	"	"	"
5	"	"	0.26328	1.983	1832	4	200	1.233 × 10⁷	5.4
6	"	"	0.44988	3.755	3469	4.5	225	1.387	6.0

For the plot of these results see the curve sheet of the preceding page.

Efficiency test. Motor driving 1/8 H.P. D.C. Supplied with 65 Volts.

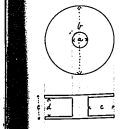
Energy supplied in effort w.	Speed r.p.m.	r.p.s.	Balance.	Moment	Moment 6165	Energy absorbed w.	Friction (Approx. only)	Effic.: η	Comm.: γ
29.5	2480	41.33	50 @ 0	0		0	29.5	0.857	
41.1	2698	44.97	50 @ 9.1	455	2.805 × 10⁶	12.6	28.5	0.829	0.254
52.0	2486	41.43	50 @ 19.6	975	6.01	24.9	27.4	0.744	0.354
63.3	2130	35.5	50 @ 19.5 / 100 @ 1.0	1975	12.18	43.2	20.1	0.639	0.436
67.2	1905	31.75	50 @ 22.5 / 100 @ 15	2525	15.57	49.4	17.8	0.560	0.411
66.3	1719	28.65	50 @ 22.2 / 100 @ 15	2860	17.63	50.5	15.8	0.503	0.384
91.2	1983	33.05	50 @ 25.4 / 100 @ 15	3270	20.16	66.6	24.6	0.508	0.371
84.8	2208	36.8	50 @ 26.1 / 100 @ 15	2805	17.30	63.7	25.1	0.573	0.407
84.1	2539	42.32	50 @ 23.2 / 100 @ 15	2160	13.32	56.3	27.8	0.650	0.435
64.2	2962	49.37	50 @ 19.3	965	5.95	29.4	34.8	0.782	0.388
49.5	3160	52.67	50 @ 8.9	445	2.74	14.4	35.1	0.843	0.248
41.0	3426	57.1	-	0		-	41.0	0.872	-

Dimensions and Data of Search Coil 10th Feby 91.

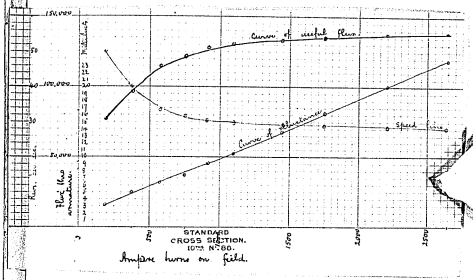
a = 0.644 b = 2.520 c = 0.914 d = 0.885 e = 1.14

3278 turns + covered to 0.0

of 0.002" (0.00508) copper wire



φ	ρ watts	L (emu) $\times 10^{-9}$
138,700	23.9	16,240
137,200	20.1	16,060
135,800	16·25	15,900
133,000	13.6	15,610
130,300	10.4	15,260
128,200	9.0	15,010
122,300	7·7	14,320
114,900	6·3	13,460
96,580	4·9	11,310
77,560	3·13	9,080



Test of ¼ H.P. Motor 9½ February 1891.

This motor weighs complete, with pulley 2.8 ℔s.
The armature is wound with 302 turns of wire each 0.018" cond. to 0.026".
The field is wound with 450 turns of wire 0.049" cond. to 0.061".
The resistance of the field is 1.05 ω @ 18° C.
" inductance " " " 133.6 h. with the armature in place and using testing current.
" resistance " " armature between brushes is 9.1 ω @ 18° C.
" " " " " " 10.25 ω hot
" inductance " " " " " "
" resistance of one coil of the armature without the platinoid wire is 0.80 ω cool.

Platinoid wire 0.007": Eureka 0.051 (0.002) separately exciting and 121 v. a mk.

1st Test. Characteristic curves

Ref. No.	Weight lbs.	Amps.	Amp. turns. ×10	MMF	Lamps in field ckt.	Speed r.p.m.	Speed r.p.s.	Rising temp.	Amps. in armature	Drop in armature	EMF generated	EMF per amp.
								0.0398				
1	1·125	5.866	2640	3320	15	1680	28·0	0·0524	0·395	3.6	117.4	4·194
2	0·935	4·876	2194	2758	12	1700	29·3	"	"	"	"	4·148
3	0·748	3·901	1756	2207	10	1715	28·6	"	"	"	"	4·105
4	0·615	3·207	1443	1814	8	1750	29·2	"	"	"	"	4·020
5	0·461	2·405	1082	1360	6	1790	29·8	"	"	"	"	3·940
6	0·39	2.034	915	1150	5	1820	30·3	"	"	"	"	3·940
7	0·32	1·669	751	944	4	1900	31·7	0·0557	0·417	3·8	117·2	3·697
8	0·246	1·283	577	725	3	2020	33·7	0·0582	0·439	4·0	117·0	3·697
9	0·159	0·829	373	469	2	2395	40·0	0·0612	0·461	4·2	116·8	3·473
10	0·092	0·428	193	243	1	2990	49·8	0·0612	0·461	4·2	116·8	2·345

2nd Test. Friction test.

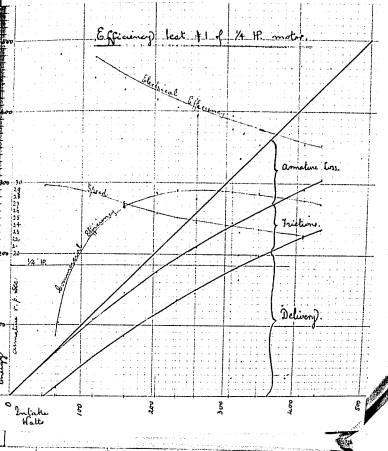
When running at 1770 r.p.m. the following observations were made.

No. of Obs.	Initial Speed r.p.s.	Initial angular velocity	Condition during retardation	Angular Acceleration $\frac{d\omega}{dt}$	Time of stopping secs.	Mass of armt.	Retardation rad. of friction	Moment of journal friction (gm-cm)	Moment of brush friction (gm-cm)	Moment of obs. journal friction (gm-cm)	Moment of Inertia estimated
1	29.5	185.3	Field & brush off	3.25	57	2.640 gm	6 mm.	309.			9.586×10^6 cm² gm.
2	"	"	Field off brush on	6.18	30			~~584~~	279	Field (309) (588)	
3	"	"	Field on	12.35	15					586 (1178)	

Flanted motor, drove it from the Edison 250-watt machine.

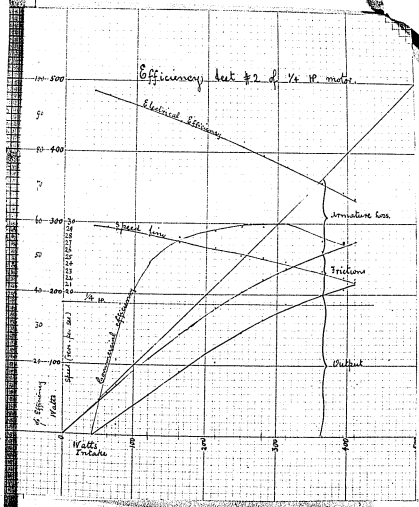
Ref. No.	Speed r.p.m.	Speed r.p.s.	Amps. in field ckt.	Amp. turns.	MMF	Balance g	Moment	6165 × Moment (Watts)	Watts per loop	Moment of Inertia (C.G.S.)
1	1860	31	0	~~1540~~		50 @ 18.2	910	174	0.56	·892
2	"	"	1	193	243	50 @ 24.8	1240	23.7	0.76	1210
3	"	"	2	373	469	100 @ 10. 50 @ 13.7	1685	32.2	1.04	1656
4	"	"	3	577	725	100 @ 10 50 @ 21.0	2050	39.2	1.265	2012
5	"	"	4	751	944	100 @ 10 50 @ 22	2250	43.0	1.39	2214
6	"	"	5	915	1150	100 @ 10 50 @ 24	2450	46.8	1.51	2405
7	"	"	8	1443	1814	100 @ 10 50 @ 32.2	2610	49.9	1.61	2564

No. of Obs.	P.D. at motor term.	Wbach	amperes	Energy in motor	Rev. per min.	Drop in armt.	Energy wasted in armt.	E.M.F. generated	Energy exerted in effect	Speed rpm	Speed r.p.s.	E.M.F. per rev. per sec.
1	124·0	0·10	0·522	64·7	9·10	4·75	2·4	119·3	62·3	1767	29·45	4·05
2	122·0	0·105	0·548	66·9	9·3	5·1	2·8	116·9	64·1	1760	29·33	3·986
3	121·2	0·186	0·970	117·5	9·5	9·2	8·9	112.0	108.6	1707	28·45	3·936
4	120·5	0·255	1·33	160·2	9·7	12·9	17.1	107·6	143·1	1618	26·97	3·990
5	118·3	0·329	1·716	203.0	9·8	16·9	28·8	101·5	174·2	1545	25·75	3·942
6	117·2	0·380	1·982	232·3	9·9	19.6	38·8	97·6	193·5	1505	25·08	3·893
7	116·2	0·428	2·232	259·3	10·0	22·3	49·7	93·9	209·6	1460	24·33	3·860
8	120·	0·495	2·581	309.7	10·1	26·1	67·3	93·9	242.4	1470	24·5	3·833
9	118·1	0·566	2·951	349·5	10·2	30·1	88·9	88·0	259.6	1405	23·4	3·760
10	119·7	0·660	3·441	411·8	10·3	35·4	121·7	84·3	290·1	1350	22·5	3·747
11	123	0·678	3·535	434·8	10·3	36·4	128·5	86.6	306·3	1350	22·5	3·850
12	121	0·-	0·395	47·8	9·1	3·5	42·4	117·5	46·4	1770	29·5	3·983



The motor was then taken apart and the platinoid wire exchanged from 0·0075 to 0·0065
0·0078 0·0126
Resistance of armature across a diameter 11·24 ω including platinoid wire
" " " 8·646 ω excluding " "
" " Inputter 9·81 ω including " "

No. of Obs.	P.D. at Motor term.	Wbach	amperes	Energy	Rev. per min	Drop in armt.	Energy wasted in armt.	E.M.F. generated	Energy exerted in effect	Speed rpm	Speed r.p.s.	E.M.F. per rev. per sec.
1	120·5	0·066	0·344	41·5	9·8	3·4	1·2	117·1	40·3	1770	29·5	3·97
2	"	0·100	0·522	62·9	9·9	5·2	2·7	115·3	60·2	1768	29·47	3·91
3	122·5	0·120	0·626	76·7	10·0	6·3	4·0	116·2	72·7	1745	29·1	3·99
4	"	0·188	0·980	120·1	10·1	9·9	9·5	112·6	110·3	1690	28·17	4·00
5	119·25	0·261	1·361	162·3	10·2	13·9	18·5	105·4	143·5	1645	27·4	3·85
6	120·5	0·340	1·773	213·6	10·3	18·3	32·5	102.2	181·1	1600	26·67	3·83
7	119·25	0·400	2·086	248·8	10·5	21·9	45·6	97·4	203·2	1545	25·75	3·78
8	119·25	0·450	2·347	279·9	10·7	25·1	58·8	94·2	221·1	1512	25·2	3·74
9	119	0·500	2·623	313·4	10·9	28·7	75·6	90·3	237·8	1477	24·6	3·67
10	119·5	0·588	3·051	364·6	11·1	33·9	103·5	88·6	261·1	1400	23·3	3·67
11	119	0·660	3·442	409.6	11·3	38·9	133·9	80·1	275·7	1345	22·4	3·58
12	119	0·638	3·327	395·9	11·3	37·6	124·9	81·4	271·0	1315	21·9	3·72



There was less spark at the brushes on full load.

When running at 1765 rpm. the armature stops in 23 seconds with field off brushes
63·5 " " " " on "
11·0 " " " " off "
12·25 " " " " off "

Tests of ¼ H.P. motor (Efficiency test #1) 9.12.91 (91

Motor mounted, and its fields separately excited, driving the 250 Watt Edison Lithurgy machine. Results as follows:

Balance	Moment	6165 Moment	Delivery Watts	Commut. efficiency	Elect. Efficiency	Runs Comm.	amps in field 0.328	A.T. on field	Friction	Remarks	Changes in Apparat.
50 @ 12.0	600	3.699	10.9	0.169	0.962	0.3872	2.917	1312	51.4	dyn. light	
500 @ 10 / 50 @ 15.2	760	4.686	13.7	0.205	0.958				50.4	dyn. S.E.F.	
500 @ 5 / 50 @ 13.2	3160	1.948	55.4	0.472	0.953				53.2	1 λ	
500 @ 10 / 50 @ 23	5115	3.153	85.0	0.531	0.893				58.1	2	
500 @ 15 / 50 @ 4.3	7285	4.491	115.6	0.570	0.858				58.6	3	
500 @ 15 / 50 @ 28	8700	5.361	134.5	0.579	0.833				59.0	4	
500 @ 20 / 50 @ 10.5	9.600	5.918	144.	0.556	0.803				59.6	5	
500 @ 20 / 100 @ 10 / 50 @ 6.2	11,825	7.290	178.5	0.577	0.783				63.9	6	
500 @ 20 / 100 @ 22.5 / 50 @ 26.5	13.835	8.528	199.5	0.573	0.796				60.1	8	
500 @ 15 / 50 @ 29	16,400	10.11	227.5	0.553	0.764				62.6	10	
500 @ 15 / 50 @ 29.3	16,935	10.43	234.7	0.540	0.704				71.6	10 with Water Rheostat 1/4 of a turn	
—	—	—	—	—	0.971				46.4	dim.	

There was a little too much sparking at full load.

Balance	Moment	6165 × Moment	Delivery Watts	Comm. eff.	Elect. Effi.	Runs Comm.	amps in field	A.T. on field	Friction	Remarks	
50 @ 0	0				0.97	0.387	2.917	1312	40.3	dim:	
50 @ 14.2	710	4.377	12.9	0.205	0.957				47.3	dyn light	
50 @ 18.3	915	5.641	16.4	0.214	0.948				56.3	dyn S.E.F.	
100 @ 20 / 50 @ 27.5	3375	2.081	59.6	0.488	0.918				51.7	1 λ	
500 @ 10 / 50 @ 7.4	5370	3.311	90.7	0.54	0.884				52.8	2 λ	
500 @ 15 / 50 @ 14.4	7520	4.637	123.7	0.58	0.848				57.4	3 λ	
500 @ 20 / 50 @ 12.5	9250	5.703	146.9	0.59	0.817				56.3	4 λ	
500 @ 20 / 50 @ 12.5	10,625	6.550	165.0	0.59	0.790				56.1	5 λ	
500 @ 20 / 50 @ 18	12,390	7.638	188.0	0.60	0.759				59.8	6 λ	
500 @ 15 / 500 @ 5 / 50 @ 27.5	13,875	8.554	199.3	0.55	0.716				60.8	8 λ	
500 @ 15 / 500 @ 5 / 50 @ 27.5	15,850	9.772	219.0	0.535	0.673				56.7	10 λ	
500 @ 20 / 100 @ 5 / 50 @ 27.5	15,435	9.516	205.4	0.526	0.694				62.6	10 λ	after 3 hrs

Determination of Series Field Winding for ¼ H.P. motor

Allowing 375 A.T. for light load with 0.46 amp. = 815 turns.
The diameter of the core above insulation = 1.72". the ext: diam: 3.3".
The mean diameter of winding 2.5" = 7.85" = 0.654' ∴ 815 turns = 533'.
The weight may be 2.5 lbs. at most = 2132' per lb. = either 19 or 20 B.W.G.
2.5 lbs. of #19 @ 1.25 ω per lb = 3.1 ω drop at 3 amp: 10 volts
2.5 " " #20 @ 2.6 ω " " = 6.5 ω " " 3 " 19.5 "
The interlinkage being 4" 0.7854 (2² − 1.72²) × 4 = 2.5 × 5.55 ∴ ∝ =
2.5 lbs of #19 @ 187' per lb = 467.5'
3.0 lbs. of #19 @ 157' " " = 561' = 3.75 ω drop at 3 amp 11.25 v. energy 33 w

Friction test of 1/16 H.P. motor 12th Feby. 91 after fitting with solid pole-pieces.

The motor was separately excited and driven by the Library 250 volt motor. The 1/16 H.P. field was varied and power absorbed noted —

Test No.	Watts	Amp.	Amp-turns	Lamps	Speed of armature r.p.m.	Speed of armature r.p.s.	Balance	Moment	Watts × Moment	Energy	Condition
1	0	"	-	-			50 @ 2.0	140		2.47	Brushes off
2	0	"	-	-	1720	28.53	- @ −2.6	280		4.37	"
3	0.081	0.423	391	1			@ −5.8	540		9.52	"
4	0.152	0.733	733	2			@ −11.0	650		11.46	"
5	0.240	1.251	1156	3			@ −11.3	665		11.73	"
6	0.308	1.606	1484	4			@ −11.4	670		11.82	"
7	0.575	3.000	2772	8			@ −11.8	690		12.17	"
8	0.710	3.703	3420	10	1705	28.42	@ −12.0	700		12.35	"
9			3420	10	1705	28.42	@ −15.2	861		15.18	Brushes down
10			2772	4			@ −13	750		13.23	"
11			1856	3			@ −12.5	725		12.79	"
12			691	1			@ −12	700		12.35	"
13			-	0	1730	28.83	@ −6.9	445		7.85	"
14				0	~~1730~~						

(Split field) Increasing the amp. turns from 0 to 3400 adds 7.4 watts to the friction
(Combined.) " " " " " " " " 4.7 " " "

On the resistance of platinoid wire drawn by mm: gauge.

Diameter cms	Diameter Inches	Area sq.cms	Area c. mils.	Resisting constant.	Res. per cm.	Res. per foot	Res. per cm. of circ.	Res. added to armt: effective
0.010	0.00394	0.000078	15.52	4.037×10^{-6}	5.14×10^{-9}	15.66		
0.012	0.00473	0.000131	22.37	3.44×10^{-6}	3.57 "	10.88 9%	3.042×10^{-9}	
0.014	0.00551	0.000189	30.16	3.41×10^{-6}	2.624 "	8.00 6%	2.216	
0.016	0.00630	0.000201	39.69	3.38×10^{-6}	2.007 "	6.12 3%	1.680	
0.018	0.00709	0.000254	50.26		1.606 "	4.894		
0.020	0.00787	0.000314	62.09		1.285 "	3.916		

Field winding adopted on ¼ H.P. motor 14 layers of 66 turns each (924 turns) of 0.042" wire #19 B.W.G. s.c.c. to 0.051".

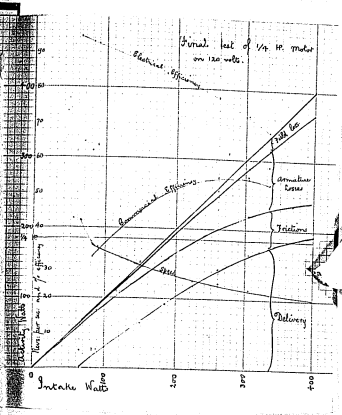
No. of Obs.	P.D. across brushes Volts	Speed Revs. per min.	Ampères in armature	Energy in watts	Mean P.D. across field Volts	Ampères in field	Energy in field watts	Energy lost in armature watts	Mean ampères in armature	Drop in ampères in armature	Energy lost in armature watts	Efficiency of armature
1	118·5	0·105	0·545	64·6	2·32	1·37	0·70	63·9	9·45	5·18	2·8	61·1
2	119·0	0·132	0·658	81·9	2·33	1·60	1·1	80·8	9·60	6·61	1·5	76·2
3	120·0	0·144	2·751	90·1	2·34	1·76	1·3	88·8	9·75	7·32	5·5	83·3
4	120·5	0·235	1·226	147·7	2·35	2·88	3·5	144·2	9·90	12·13	14·9	129·3
5	120·0	0·295	1·538	184·6	2·36	3·63	5·6	179·0	10·05	15·46	23·8	155·2
6	120·0	0·359	1·872	224·6	2·37	4·44	8·3	216·3	10·20	19·10	35·8	180·5
7	121·0	0·409	2·133	258·1	2·35	5·08	10·8	247·3	10·35	22·07	47·1	200·2
8	120·0	0·466	2·539	304·0	2·39	6·06	15·4	288·6	10·60	26·86	68·1	220·5
9	118·5	0·540	2·816	334·6	2·41	6·79	19·1	315·5	10·85	30·53	86·1	229·4

PARTICULARS OF EDISON MODEL 1/4 HORSE POWER MOTOR.

Weight without wooden base 26 1/4 lbs.
with wooden base 28 3/4 lbs.
Winding shunt-wound and series field.
Voltage 120 at terminals
Amperes at delivery of 1/4 HP. 3.0
running light 0.55
Commercial efficiency at delivery of 1/4 HP. 50%
" " " " " 1/8th H.P. 30%
" " " " " 1/16 HP. 54%
Speed running light 2500 revs. per min.
at delivery of 1/4 HP. 1800 revs. per min.

Dimensions :-
Armature body diameter external 6" internal 4"
Number of grooves 42 on each side.
Breadth of armature body over teeth 1.182"
at base of grooves 0.662"
Depth of grooves 0.26", breadth of grooves 0.2"
Band iron in core 0.028" annealed.
Cross-section of armature core 0.66 sq. ins., 4.29 sq. cms.
Breadth of teeth 0.21" at external, 0.06" at internal circle.
Insulation 0.01" mica and 0.001" oiled silk on bore.
Polar surface of teeth 20 sq. cms. under each pole.
Winding 42 turns, 3 layers of 14 turns each of 0.076 dia. 0.015" covered. to 0.0855"
Commutator dias. 2".
Total length of wire in armature 1000 feet.
Total weight " " " " 1.0 lb.
Resistance of armature between brushes 3.0 ohms [illegible]
Same including 0.8 connections 3.5 " " " "
Current in armature at full load 3.0 amperes
Drop in armature " " " 12 volts
Energy expended in heating armature at full load 10 watts.
Magnetic flux 55.5 lines.
Induction density in core [illegible]
Number of lines of force [illegible]

Bar diameter 0.05" [illegible]
Diameter over wire 2.0"
Wire through core area at full load 20%
Induction density of core at full load [illegible]
Winding 600 turns of wire 10 layers.
Wire # 14 B.W.G. 0.082" covered to 0.094" 2 lbs.
Resistance of field winding 2.8 ohms cold. [illegible]
Drop in field at full load 8.4 volts. 50 watts.
Total resistance of motor between terminals 11.0 and 3.2 hot
Brushes of copper gauze under 5 blocks of compressed
Connections from armature to commutator 0.8 0.0625"


Trial test of 1/4 H.P. Motor
on 120 volts.
Electrical Efficiency
Watts lost
Commercial Efficiency
Armature losses
Frictions
Field
Delivery
Intake Watts

Trivial Tests of ¼ HP Motor 13½ – 14th February

The field winding was adjusted to 16lbs 15ozs of #19 BWG 0.042" to 0.051".
Leaving 10 layers of 66 turns or 660 turns in all. Series wound
& Efficiency test driving Library model, 250 Watt machine sepi. exc.

Speed rpm	rpm	Load ins ⌀	Moment	Gross Moment	Driving W.	Friction Watts	Gross eff.	Elect. eff.	EMF generated	Amps. Trans	Output
							42·3	0·945	112·0	3·61	Lights dim
2535	4·225	50 ⌀ 0	0								
2125	3·542	50 ⌀ 24	1200	7·4×10⁶	26·05	0·318	50·1	0·931	110·8	4·54	Lights Lights
2070	3·45	50 ⌀ 26	1300	8·01 "	27·6	0·337	55·7	0·925	111·0	4·96	" S.E.R.
1825	3·042	{50 ⌀ 20 / 100 ⌀ 25}	3500	2·158 "	65·6	0·444	63·7	0·877	105·6	8·09	1 λ
1645	2·74	{500 ⌀ 3 / 5000 ⌀ 10}	5450	3·360 "	92·1	0·499	63·1	0·841	100·9	10·15	2 λ
1530	2·55	{50 ⌀ 15 / 500 ⌀ 15}	7875	4·670 "	119·1	0·530	61·4	0·812	97·5	12·35	3 λ
1470	2·45	{50 ⌀ 17½ / 500 ⌀ 20}	9450	5·827 "	142·8	0·583	57·4	0·776	93·9	14·08	4 λ
1365	2·275	{50 ⌀ 17½ / 500 ⌀ 25}	11,750	7·244 "	164·8	0·542	55·7	0·726	87·1	16·73	5 λ
1280	2·133	{50 ⌀ 19·5 / 500 ⌀ 25}	13,490	8·316 "	177·4	0·530	52·0	0·682	69·1	18·58	8 λ

There was a little brushless sparking at the brushes during full load.

20 ϕ in field = 5460 ϕ-lines per sq cm = 10920 AT per cm = 13720 MMF

1240 volts = 1753 Max: on S. H.

$20.2 \times 16 \times 5.12 = 1.655 \times 10^5$

$1753 \div 1.655 = 1.059 \times 10^{-2}$ Webers

$13720 \div 1.059 = 1.296 \times 10^{-3}$ Lines.

Test of the Alternator described on p. 138 Book III.

Schenectady 16th February.

The pole-core circle has been bored out to 23 3/16 dia. 4 Bands 3/4" wide of #19 B.W.G. Phosphor-bronze wire on 1" micas.

Res: of the field is 5.87 Ω @ 15.5° C.

" " armature is 1.2 Ω.

Weight of the armature complete

" " field-frame

When running at 1212 revs. on the first occasion, the bands flew off the armature. On this account the field was bored out to its present dimensions. Bands of same of phosphor-bronze wire 0.6 Ω were then layed on soldered.

When running the second time at 1212 revs. with 120 volts on the field and a Cardew voltmeter of 586 Ω across the pole in circuit with 7782 Ω of inductanceless wire making a total of 8350 Ω multiplying power of 14.7 the volts shown (effective) were 83 = 1240 effective volts. 12 lamps were also brought up to candle power. Within a few seconds however, the bands burst from the armature, almost destroying it.

Test of No 2 Edison Experimental A.C. Motor

The motor with its field rearranged as described on p. 131 Book III.

The fields were excited from 500 volts, and 500 volts also through the armature. 512 bars in commutator + 4 brushes of brass plates

With 500 volts on field	1.83 amperes	110 volts on armature	56 r.p.m.
" "	"	500 " "	248 r.p.m.
" "	1.1 "	500 " "	300 " "
" "	0.7 "	500 " "	400 " "

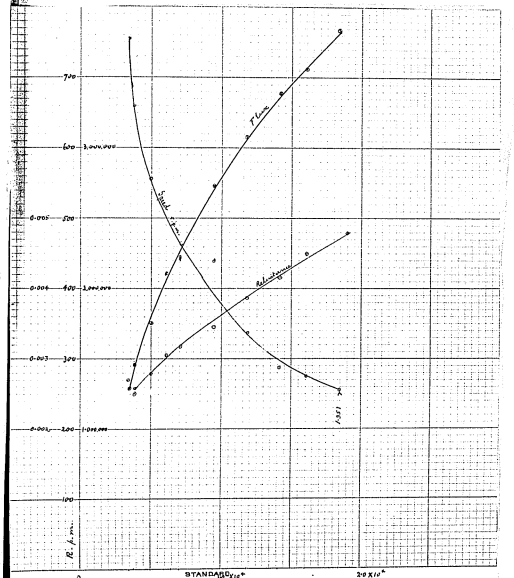
Test of the Alternator continued 17. II. 91.

The tendency of the fields to rise in temperature, under excitation was determined with the armature removed. On starting, the EMF on the coils was 1300 the current 25 A and res: of all coils in series 5.2 Ω. after 65 min, the p.d. was 1210, the current 22, and the res: 5.5 Ω, after 4 hours, the p.d. was 120 the current 18.5, and the res: 6.49, a rise of 24.8% = 64° C. The temp: by thermometer on the coils also reached the maximum limit of 85° C = 70° C rise. One coil was found to be faulty short-circuited, even at the commencement of the test.

The armature was patched up, and bound with 2.95 c. phosphor bronze wire bands in widths of 4, soldered only on the outside wire. In running the armature at 1280 r.p.m. there was an initial clearance of about 1/8" all round. After raising the field slowly to full power, it shortly became evident that some part of the armature was rubbing against the pole, and on stopping, the armature was found to have enlarged radially.

The Westinghouse alternators run at about 1650 r.p.m. and their armatures are 21" in diam: (approx.) = 9075' per min.

r	q
4.79×10^{-5}	2.838×10^{5}
4.51	3.538
4.16	3.348
3.84	3.072
3.45	2.734
3.19	2.220
3.05	2.106
2.79	1.756
2.51	1.501
2.37	1.468
2.70	1.292



Determination of the winding for the #2 motor clutches when inserted in the field circuit. 19th Febry. 91.

From the record of page 76 it is evident that 2000 amp. turns are needed in each clutch. Allowing 1.75 amp. in the circuit, the no: of turns = 1140. The mean radius being 7.5", the circumference is 47 say 4'. So that the total length is 4560' of wire. The winding space is 47 × 0.925 × 1.8 = 78.4 c.in. = 14 lbs. 14 lbs for 4560' = 326' per lb. = #21 B.W.G. 0.032" s.c.c. & 0.041". = 32 turns and 44 layers = 970 turns = 3880' = 11.6 lbs. say 12 lbs. of #21 B.W.G. @ 4.19 = per lb. = 50 a coil = 100 a. This is prohibitive.

Allowing 500 amp. turns. @ 1.7 amp = 300 turns = 1200' = 185' per lb. = #17 B.W.G. 0.054" cover. & 0.078". = 12 turns and 25 layers = 300 turns. 14 lbs. of this wire. @ 0.24 per lb. = 3.60 = 7.20 a pair in series.

Allowing 800 amp. turns @ 1.7 amp = 470 turns. = 1880' at 13 lbs. = 144' per lb. #18 B.W.G. 0.049" cover. & 0.059". = 16 turns × 32 layers = 512 turns. at 132 per lb. = 132' per lb. = #16 B.W.S. 0.051 cover. & 0.061". = 15 turns × 30 layers = 450 turns. 14 lbs @ 0.66 & per lb. = 9.24 a coil = 18.48 a in series.

Test of the #2 S.C. motor in the new field 19th February 1891.

This motor is mounted in the fields described on f.131 Book III.
The following observations were made :—

No.	P.D. on motor	Speed	Speed reduced to 500 r.	Current in field	Current in armat.	No. of armat.	Drop in armat.	EMF of armat.	Pole of field	Remarks	Amp T.
										Coil spare 37.00 turns common.	
1	512	260	254.6	1.95	1.05	1.53	1.4	510.6	262.5	No sparking	14,630
2	-	280	274.5	1.7	1.35	2.0	2.0	510.		- 1.643	12,750
3	-	294	287.5	1.5	1.7		2.3	509.7		- 1.414	11,250
4	-	324	318.1	1.25	1.95		2.6	509.4		- 1.179	9,375
5	-	364	357.4	1.0	2.0		2.7	509.3		- 0.943	7,500
6	-	448	440.1	0.75	2.25		3.0	509		- 0.707	5,630
7	-	472	463.8	0.68	2.32		3.1	508.9		- 0.696	5,100
8	-	566	556.2	0.52	2.3		3.1	508.9		- 0.4525	3,900
9	-	662	651.0	0.4	2.6		3.5	508.5		- 0.377	2000
10	520	688	665.6	0.4	2.4		3.2	516.8		- 0.377	2000
11	524	784	756.0	0.37	4.0		5.3	518.7		- 0.3491	2775
12	During an power test of this motor it was found to deliver a dynamometer pull of 4000 lbs reducing our motors to 2500 lbs on a train of cars with a current decreasing from 94 to 60 amp.										

Sparking experiments.

Motor running at 500 volts t. p. d.

1.85 amp. in field 2.2 in armt. 256 r.p.m.
0.65 . . 27 . . no sparking appreciable
0.4 . . 45 . . some but not bad sparking
0.30 . . 62 . . 668 . . . . .
0.38 . . 72 . . 734 . . . . .

Results of brushing the 20. Kilowatt machine at Schenectady, with ½" cylinder all round the poles.

With 200 amperes 40°C rise after 2¾ hours trial before brushing.
- 320 . . 39°C . . 5 . . " after " "

Test of the Carrying Capacity of Carbon brushes 20.II.01

A Sprague armature was disconnected from its commutator. This commutator was stripped with about 100 turns of fine copper wire on its outer rim to connect all the bars together. The diameter is 6", (the periphery 19"). 56 bars separated by mica about 1/16" wide. The brushes were of carbon very slightly copper. 1 3/4 x 1 3/4 x 1/2" and held in the brush holder up to about 1/2" from the commutator. By means of a pulley and belt, this armature was run from a motor and current passed between the brushes. There was comparatively little sparking up to 100 amperes on these brushes offering a maximum contact surface of 3/4 sq. in. between 992 and 1312 revs.

At 1312 revs. per min. and	105 amp.	the p.d. between brushes was	6.2 v = 0.06 ω
	75		5.8 v = 0.075 ω
	50		4.1 v = 0.082 ω
	30		3.0 v = 0.100 ω
at 1100	100		5.8 v = 0.058 ω
	75		5.2 v = 0.07 v
	50		4.2 v = 0.084 ω
	35		3.6 v = 0.103 ω
	25		3.2 v = 0.128 ω

Data Concerning Street Railroads obtained on the 20th Febry.

Weight of the Westinghouse ordinary cast. iron 15 H.P. motor + gears 2570 lbs.
- " " Sprague No. 6. 15 HP " " 1600.
- " " #2 new Edison experimental 30 HP " " 4240.

The average at Pittsburg of current by ammeter with 58 cars out (Sprague cars) was 580 amperes (10 per car) with 500 v. station pressure falling to a mean of 450 in the main.

The W. & T.H. motors average about 17 amp. per car owing to the use of resistance in the armature circuit.

The use of iron link wire between rails is undistinguishable.

Rails should also be frequently grounded, this saves interference with telephonic systems.

Sprague no. 6. motors are tested for one hour with a steady current of 25 amperes. The usual temp attained on the armature is 50 – 55° C. above 35° C. rise.

Sprague motors occasionally take 100 amperes each for short intervals.

Westinghouse motors will run on light loads up to 20 miles per hr.

All motors in Street Car service employ Series Fields.

For the first three or four days the wheels slack on the track, when electric cars are first introduced on a line, after that, the only source of bad contact is generally dry snow.

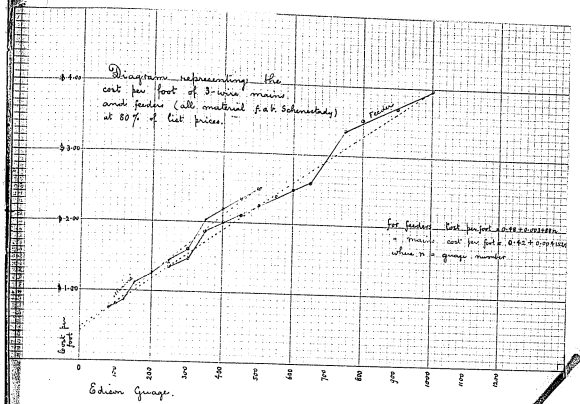
T.H. motors will run at 8 m.p.h. without rev. inserted.

The average schedule speed of motor cars in Pittsburg including stoppages is 6 mph. On the suburbs, and early or late, in the city it attains 12 mph.

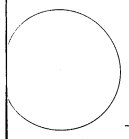
Whenever a single motor car is geared to one axle only, the car fails to mount grades in slippery weather. The fact does not give rise to much annoyance because sand is thrown on the rails.

All the parts of a motor are subjected to severe mechanical strain and vibration, and frequently crosses in the fields of a Sprague are traceable to loosening of the magnet by constant shaking

Diagram representing the cost per foot of 3-wire mains and feeders (all material f.o.b. Schenectady) at 80% of list prices.



Calculation of the most economical distance for Feeding points in circular Distribution.



The accompanying diagram shews that to a fair degree of approximation, the cost of feeder or mains per foot as brought but not layed is of the form $\alpha + \beta d^2$, where α and β are constants and d is the diameter of the conductor (outside) in mils.

For feeders cost per foot $ = $ 0·48 + 3·488 × 10^{-6} d^2

" mains " " " = 0·42 + 4·152 × 10^{-6} d^2

The cost of laying, including trenching, jointing and testing may be estimated as another constant δ, it will be greater for larger tubes but where there are larger tubes there will be generally more in one trench so that δ may be regarded as constant per foot.

Now consider a system whose mains are a series of concentric circles. We will assume that these circles are cross connected by radial mains whose number shall be independent of the number of feeders we employ, and also that all the feeders shall be true radii, not subdivided, as is now so customary.

Then let R be the radius of the supply circle (in feet)

m " " permissable drop in the mains (volts)

f " " " " " feeders (volts)

I " " total current on one outside conductor supplied by the feeder or feeders (amperes)

ρ " " resistivity of copper per cubic foot at stg. temp. in ohms.

d " " diameter of the outside conductors

n " " number of feeders employed, at uniform distances apart

c " " cost per foot of layed conductor

C " " total cost " "

Then with n feeders

$$\frac{I}{2m} \cdot \frac{2\pi R}{+n} \cdot \frac{4\rho}{\pi d^2} = m$$

$$\therefore d_m^2 = \frac{RI\rho}{mn^2}$$

$$c_m = \delta + \alpha_m + \beta_m \cdot \frac{RI\rho}{mn^2}$$

$$C_m = 2\pi R\left(\delta + \alpha_m + \beta_m \frac{RI\rho}{mn^2}\right)$$

Also with n feeders

$$\frac{I}{n} \cdot R \cdot \frac{4\rho}{\pi d_f^2} = f$$

$$d_f^2 = \frac{4RI\rho}{\pi n f}$$

$$c_f = \delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}$$

$$C_f = n R\left(\delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}\right)$$

$$C_m + C_f = R\left\{2\pi\left(\delta + \alpha_m + \beta_m \frac{RI\rho}{mn^2}\right) + n\left(\delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}\right)\right\}$$

$$\frac{d(C_m+C_f)}{dn} = R\left\{2\pi\beta_m \frac{RI\rho}{m}\cdot\frac{-2}{n^3} + \delta_f + \alpha_f\right\} \text{ a minimum}$$

for min: $\delta_f + \alpha_f = \dfrac{4\pi\beta_m RI\rho}{mn^3}$

or $n = \sqrt[3]{\dfrac{4\pi\beta_m RI\rho}{m(\delta_f+\alpha_f)}}$

and $\dfrac{2\pi R}{n} = \dfrac{2\pi R}{\sqrt[3]{\frac{4\pi\beta_m RI\rho}{m(\delta_f+\alpha_f)}}} = \dfrac{\pi R}{\sqrt[3]{\frac{\beta_m RI\rho}{2m(\delta_f+\alpha_f)}}}$ = economic distance.

$$= \sqrt[3]{\frac{R^2}{I}} \times \sqrt[3]{\frac{2m(\delta_f+\alpha_f)}{\beta_m\rho}}$$

$\therefore x = \sqrt[3]{\frac{R^2}{I}} \times 90$

If $\beta_m = 4{\cdot}152 \times 10^{-6}$ $\rho = 10$

$\pi^3 = 10$ $m = 1$ $(\delta_f + \alpha_f) = 1$

It appears that δ_f is nearly constant and $= 30000$

$\therefore x = 1150$.

Trial of a small Perret Motor, sent to the Laboratory for the Manufacturing Co. to be tested on a Falconde Edison Battery 22nd Feby. 91.

Res: of this series wound motor Fields. ~~0.129~~ 0.129 Armature 0.185 } Total. 0.314

Worked on 8 cells of battery) battery that have been set up about two months. E.M.F 5·8 v. after work. P.D. on motor 4.0 Current averages 3·69 A = 14.6 watts in motor $\frac{1}{20}$th H.P. Speed of fan about 1260 rpm. Test satisfactory. Res: of battery, wire leads + galvo $\frac{5.8-4.0}{3.65} = 0.5\Omega$ or 0·0625 ω per cell.

With 6 cells fd. 3.1 v. 0.68 (0.192) amps. 1000 rpm. = 3·47
" 4 cells 2.1 0.47 660 " = 2·57.

Magnetic Test of ¼ HP Motor 14th February 1891.

No. of Wire	E.M.F.	Bonds.	a	Mean thro'	No. of turns	q. per cir.
1	1·143147	19	$1{\cdot}143147 \times 10^{-7}$	125·0	144	$1{\cdot}1148 \times 10^{-9}$

T... of Ma.	Wheat.	Amp.	Amp turns	MMF	No. of turns	Mean	φ	β	ρ	Winding
1	0·042	0·219			3	60				5 turns round field centre
2	0·092	0·428			2	128				
3	0·170	0·887			2	215				
4	0·320	1·669			2	317·5				
5	0·588	3·067			2	400				
6	0·042	0·219			2	65				10 turns round Knees
7	0·092	0·428			2	107·5				
8	0·170	0·887			2	183				
9	0·320	1·669			2	293				
10	0·588	3·067			2	295·5				
11	0·042	0·219			2	23·5				5 turns round armature between pole faces
12	0·092	0·428			3	47				
13	0·170	0·887			2	76·5				
14	0·320	1·669			3	100				
15	0·588	3·067			2	112				
16	0·588	3·067			1	112				5 turns below

Determination of the winding for a 6% grade Edison Motor
2nd March 1891. Basis — quadripolar, gramme-ring armature, to pull a 20,000 lb car up a 6% grade, at slow speed — 4 miles per hour, on full load.

Pull = 12,000 + 10 × 15 = 1350 lbs wt. at axle 30" diam car wheel = 1688 ft lbs

Velocity ratio 5" = 337.6 ft×lbs at armature at full load.

Speed 250 to 750 rpm of armature = 50 to 150 rpm of car wheels = 4.166 to 13.4 miles per hour

Power exerted usefully is $1350 \times \frac{22}{15} \times \frac{4.166}{737} = 12$ kwts 16 HP.

Allowing an efficiency of 0.7 = 17.14 kwts = 22.85 HP = 34.3 amp @ 500 v.

Diameter of armature 29" over all circ: 91.12" = 7'6'

Peripheral velocity 1900' per min @ 250 rpm, and 5700' per min @ 750 rpm

Flux useful flux through armature 2,400,000 lines and with $\nu = 15$
Total flux " cores 3,600,000 "

Density in armature space 8000, spaces occupied iron wire.
" " field magnets 7500 cast iron.
" " keeper " 7500 " "

Armature Dimensions.				
			circ	diam
	External diameter	29.0" over all		73.60 cms
	Binding wire	0.09"		0.23
	Diameter over conductors	28.82"	90.57	73.2 cms
	Diameter " body wire	28.10"	88.28	71.4 cms
	" " wire body	27.96"	87.66	71.0 cms
	Internal " "	27.25"	85.44	69.2 cms
	Breadth mean of core	7"	22.0	17.8 cms
	External breadth	7⅛"	22.4	18.1 cms
	Internal "	6⅜"	20.0	16.2 cms

Area of external circle of armature body 615.75 sq in. } area of annulus 271.25 sq in
" " internal " " " 354.5 " " } 1750 sq cms

Cross-section of armature core 29.625 sq in 192.4 sq cms
Volume " " 8828.7 c in 144700 c c.

Sp. gr. 5.3 = 1,588,008 gms = 158.8 kgms = 350 lbs.

Polar bore diameter 29.375" circ: 92.25" cms = 74.6 and 234.4 circ

Wire 5×10^{-4}" ÷ $4.167 \times 2.4 \times 10^{-6}$ = 5×10^{2} = 5000 wire all round.
5 layers of 1000 each, Space per wire on cent: circ 0.0985
Diameter of covered wire 0.071" d.c.c. = 0.058" = # 17 B.W.G. = 3364 cmils
Armature body insulation, 0.1". Clearance 3/16". Entrefer 1.85 cms.
Mean turn = 23" = 1.918' and total length = 9590' = 97.8 kms.
Res: 29.42 Ω cent: = 33.65 Ω hot (60°C) = 39.52 Ω hot @ 100°C.
Res between brushes without platinoid connecting wires, and assuming contact on single bars 1.84 Ω cent, 2.10 @ 60°, 2.47 Ω @ 100°C.
Drop at full load (34.3 amp) 63.1 v " 72.0 " 84.7 "
Energy spent in cores at full load of 34.3 amp 2160 watts 2470 watts 2905 watts

Torque at full load, assuming full flux thro armature per ampere
$5,000 \times 2.54 \times 10^{8} \times 10^{-8} / 6.283 = 1.91 \times 10^{8}$ dynes = 1.95×10^{5} kgms wt @ 1m
= 5.28 kgms per amp at periphery armature = 11.64 lbs per ampere.
= 399 lbs. at full load of 34.3 amp = torque of 6690 cm kgms = 484 ft lbs

Cores and keepers of cast iron 9.75" (24.76) drain = 79.66 sq in = 451.7 sq cms
length 11". Inter flange 10.5" = 26.67 cm Thickness of copper = 3/16" = 0.476 cm
Diam: over copper 10.125". Weight of copper 11 × 31.4 × 3/16 × 0.323 = 20.9 lbs
= 84 lbs of about copper in all four spools. External winding diameter 10.5".

Magnetic circuit.

			ℓ	ℌ	μ	r
Armature	Length	4/8 ins	Cross section .252	0.86	8000	0.001	0.000086
Core	"	100	"	480/2	0.417	7500	0.01	0.004·17
Centrifer	"	1.85 × 2	"	888/2	0.00833	=	1·0	0.00833
Cast iron ends	"	22 × 2	"	300/2	0.3	"	0.01	0.003
								0.01710

To force 1200 000 lines through this circuit

$1.257\ \Delta T = 1.2 \times 10^6 \times 1.7 \times 10^{-2} = 2.04 \times 10^4$

$\Delta T = 16,230$ or 8120 per spool.

The surface of each spool is about $26.67 \times 14 \times 2.5 \times 3.14 = 2930$ sq.cm. Allowing 15 sq. cms. per watt = 195.5 Watts per spool, or 20 sq. cms. per Watt 1465 say 250 Watts. = 1800 Watts in field at slowest speed. 2.0 amp. @ 500 volt all in series. = 4.060 turns per spool to have a res. of 62.5 ω but the mean turn = 325' and the total length 13200' for 62.5 ω or 211.2 feet per ω @ 60°C = either # 18 B.W.G. 0.049" or # 16 B.S. 0.051". 68.4 ω and 60.4 ω respectively. The weight = 106.8 lbs. or 92.4 lbs respectively: Say the former = 4·27 lbs. in all. Making total weight of copper on the field 5·11 lbs. The space occupied = 593 c.ins. per spool an ext. diam. over wire of 13.8" or over rep. 14.0".

Mean diam 12" mean circ. 3.14'. Wire 0.051" d.c.c. to 0.060" = 170 turns per layer + 25 layers = 4250 turns.

Energy absorbed at full load. Field. 2·0 amp 1000 watts.
armature 34·3 " 17150
Total 18,150 "

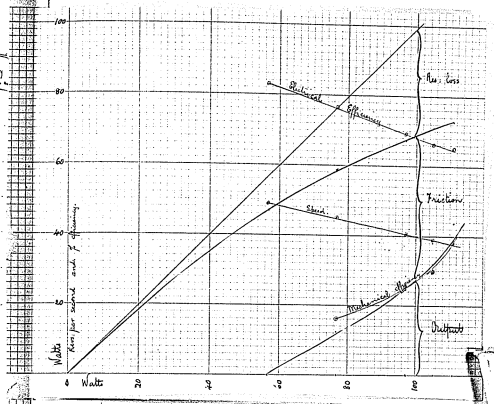
Probable delivery on 6% grade $0.75 \times 17150 =$ 12,860 " = 48 mph

Determination of the winding for the ½ HP. motor at 250 volts

The grooves in the 120 volt armatures are 0.225" × 0.225". Keeping the same depth, we have 0.21" for winding. There are 49 turns in the 120-volt groove and 90 may be allowed in the 240 volt groove or 9 layers of 10 wires each. $0.21 \div 9 = 0.0233$" and bare diam = 0.014" allowing 0.009" for insulation = # 28 B.W.G. d.c.c. There will be about 1800' of this wire @ 0.0603 ω per foot @ 60°C = 109 ω or 27 ω in the armature without including platinoid wire. The breadth will be 10×0.0233" = 0.233" + 0.025 = 0.258" say 0.26" wide.

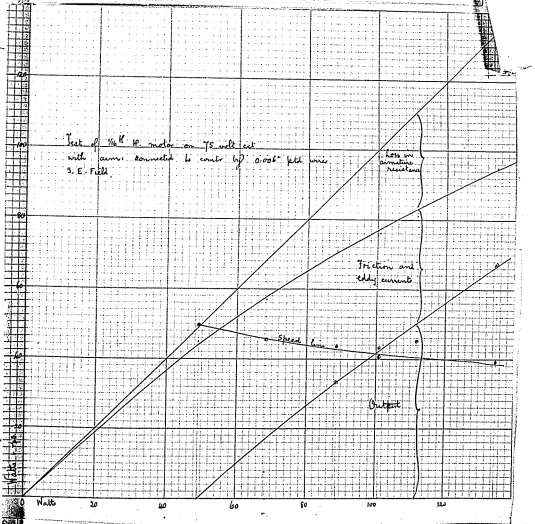
The field should be series wound, and not more than 5 ω res. @ 60°C, so that at full load the energy may not exceed 50 watts in it. The mean diam. of the coil will be about 0.75' so that with 1000 turns there will be 750' = 150' per ohm @ 60°C. = 0.042" # 19 B.W.G. d.c.c. 5 ω of this wire @ 0.8 lbs. per ω = 4 lbs. of wire

No of Obs	Bloach.	P.D. at motor term.	Amperes in armature	Energy absorbed watts	Res. of armt.	Drop in armt.	E.M.F. of armt.	Speed of armature r.p.m.	r.p.s.	E.M.F. per rev. per sec.	Energy lost in ...
1	0·1148	73·5	0·772	56·7	16·5 ω	12·7	60·8	2925	48·75	1·247	9·8
2	0·200	73·5	1·043	76·7		17·2	56·3	2725	45·42	1·241	8·2
3	0·258	72·2	1·346	97·2		22·2	50·	2433	40·55	1·233	31·9
4	0·295	72·2	1·486	107·3		24·5	47·7	2325	38·75	1·231	36·4
5	0·300	72·2	1·565	113·0		25·8	46·4	2290	38·17	1·216	46·4
6	0·288	72·2	1·502	108·5		24·8	47·4	2290	38·17	1·242	37·3



No. of Obs	P.D. at M.T.	Bloach.	Amperes in armature	Velocity in metres per minute	Drop in armt.	Activity in heating armt.	E.M.S. in armt.	Speed r.p.m.	r.p.s.	E.M.F. per rev. per sec.	Effort
1	76·5	0·123	0·641	49·0	6·74	4·3	69·8				44·7
2	77·2	0·17	0·886	68·4	12·18	10·8	65·0	2980	49·67	1·308	57·6
3	·	0·222	1·157	89·3	15·9	18·4	61·3	2745	45·75	1·340	70·9
4	76	0·251	1·309	101·1	18·0	23·2	58·0	2630	43·83	1·324	76·9
5	75·8	0·278	1·449	111·9	19·9	30·9	55·9	2600	43·33	1·290	81·0
6	75·3	0·334	1·752	135·3	24·1	40·5	54·1	2365	39·42	1·372	94·8

Test of ¼ H.P. motor on 75 volt circuit with armature connected to centre bar of field winding. S. E. Field.



Determination of the field winding for 120-watt circuits.
The current at which the motor will deliver 50 watts at 75 volts on armature terminals is 1·57. This current must produce a drop of 40 volts = 26·7 ω res. # 24 B.W.G. 0·022" has a res. of 16·63 ω per ft. ∴ 60·0 ω = 1·6 ft.
The current at which the motor will drive the fan at 11440 r.p.m. = 190 volts is 0·5 amp. so that the drop for 0·8 ϕ = 75 volts = 150 v. , 120 = 1·6 ft
28 B.W.G. g.s. wire has 1·074 ω per foot ∴ 125 feet.

Test of 1/16 H.P. motor 9th March 1831. Solid pole pieces

The last test recorded on page 90, the platinoid connecting wire have been reduced to 0.00148 and the pole pieces have been made solid instead of laminated. The motor was floated and separately excited

Balance	Moment	6165 Moment	Delivery Watts	Effort	Friction	Mech. eff.	Elect. eff.		
50 @ 0?	-	-	-	48·9	46·9		0·827		
50 @ 18·7	435	2683	12·2	58·7	46·5	0·159	0·766		
50 @ 19·8	978	6·012	21·14	67·3	42·9	0·251	0·692		
50 @ 26·8	1340	8·262	32·0	70·9	38·9	0·298	0·661		
50 @ 37·3	1865	11·50	43·9	72·6	28·7	0·389	0·643		
50 @ 37·3	1865	11·50	43·9	71·2	27·3	0·405	0·656		

Second test of 1/16 H.P. on 75 volt circ: Field separately excited, after replacing the platinoid wire with one of larger size 0·0066. Res: of armature 13·75 ω mean 3·25 ω between adjacent bars. No sparking

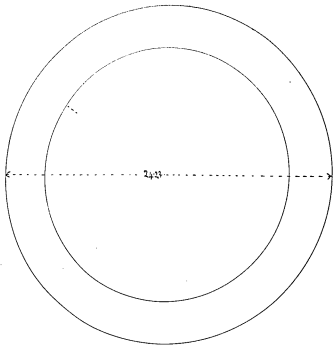
Motor driving C.C.C. 1/8 H.P. model as dynamo with S.E.F.

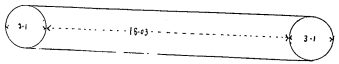
Balance	Moment	6165 moment	Driving watts	Friction	Mech. eff.	Electrical eff.	Amp. in field	Load
				44·7		0·913	2240	Life
50 @ 5·	250	1·54	7·65	50·	0·1148	0·842		⅛ C.C.
50 @ 24·0	1200	7·398	33·85	37·	0·379	0·794		S.E.F.
50 @ 29·7	1485	9·155	40·12	35·8	0·397	0·763		3 lamps
50 @ 33·7	1685	10·39	45·02	36·	0·402	0·737		2 -
50 @ 25·3 100 @ 15·	2765	17·05	67·2	27·6	0·407	0·718		1 -

When separated with its fan; on 76·5 volts the armature and fan made 2900 rpm. @ 76·5 v. + 0·165 Watts 0·86 = 66 watts

- 1440 - - @ 40·0 . . 0·095 . 0·495 = 19 watts

Plan and diametral section of ring half size.
Syracuse cast Steel





Means diameter of ring 21·13
" circumference " 66·4

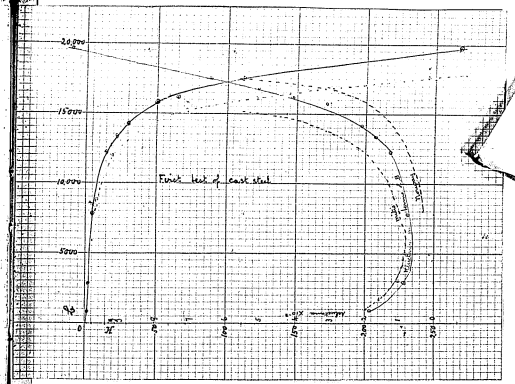
Analysis of this steel by two independent firms :-

Syracuse analysis

C 0·25 to 0·3 %
Mon 0·3 " 0·4
Si 0·15

Stratton analysis

C 0·25 %
Mn 0·36
Si 0·15
Ph 0·118
S 0·062



Test of the magnetic permeance of a ring of soft steel received from Schenectady March 5th

The winding and dimensions of this ring were all repeated after reception. The primary consists of 690 turns of #16 B.W.G. and the secondary 100 turns of #25 B.W.G. insided the primary.

No of Obs	Source of EMF	Condr.	EMF	Q	No. of Rheostat	Mean Rheostat	Mean $\frac{dH}{dt}$		
	1 c.c.	$1\gamma \times 10^{-15}$	1.43147×10^{3}	1.43147×10^{-7}	13	166.63	1.23×10^{9}		

No of Obs	Observed	Amp.	M.M.F.	No of Rheostat	Mean Rheostat	Apparent Sec.	Mean of Sec.	ϕ	φ	μ	$\frac{\mu}{1000}$
1	0.022	0.1147	1497	7	33.1	25000	34,250	4.09180^{-8}	6.158×10^{3}	816	1.835
2	0.035	0.1825	2.382	7	118.4	25,000	30,250	1.45626×10^{-7}	2.202×10^{4}	2917	0.816
3	0.056	0.2919	5.862	7	172.5	50,000	55,250	2.122 "	5.862×10^{4}	7766	0.755
4	0.22	1.1147	114.97	5	134.14	105,000	105,250	1.739 "	9.151 -	12,120	1.139
5	0.322	1.680	21.93	5	158.0	-	"	1.907 "	10.04 -	13,300	1.649
6	0.441	2.30	30.03	5	166.5	-	"	2.036 "	10.71 -	14,190	2.116
7	0.713	3.72	48.57	5	180.9	-	"	2.225 "	11.84 -	15,690	3.095
8	0.970	5.06	66.06	5	187.8	-	"	2.310 "	12.15 -	16,100	4.103
9	1.650	8.61	112.44	5	204	-	"	2.509 "	13.21 -	17,500	6.423
10	3.92	20.45	267.0	3	230	-	"	2.829 "	14.89 -	19,730	10.37

Internal diameter of ring 18.03 cm. External diameter 24.27 Mean 21.15
" circ: 56.64 " 76.24 66.44
Cross diameter " 3.1 "
" circ: 9.738 "
" area 7.548 sq. cms
Weight of ring in air 8 lbs. 10 oz 150 grains = 1350 150 grs. = 3912 + 99.
= 3921.7 gms.
" " " water
Volume of ring from measurements of diameter 501.5 c.c.
Sp. gr. of metal 7.82
$1.257 \times 47 \times 690 / 66.44$

On braiding german-silver wire with a view to increasing its carrying capacity. Mar. 11th 91.

A sample of g.s. wire has a diameter of 0.005" (0.0127) a resistance per cm. of 0.3084 ω per cm. @ 18° C, and a surface per cm. of 0.0399 sq. cm. It reached dull redness in air with a current of 1.337 and an activity per cm. of 0.709 ω day or 1.77 watts per sq. cm.

When 16 of these wire are braided together, the resulting diameter is 0.031"(0.0787) the resistance per cm. 0.0239 ω instead of 0.3084/16 = 0.01928 ω and the surface per cm. is for a round wire of equal diameter 0.24674 sq. cm. The current that heats this to similar redness is 1.40/0.1918 = 7.3 amp: an activity of 1.273 watts per cm. or 5.15 watts per sq. cm.

When one wire of equal gross section to these 16 combined, namely # 25 B.W.G. 0.020" wire tried, its resistance per cm. was 0.01144 ω, and the current required to heat it to dull redness was 7.51 amp. the diam: being 0.0501 the area is 0.1596 sq. cms, and the surface 0.1596 sq. cms. per cm. The activity per cm. would be about 1.09 watts and per sq. cm. about 6.77 watts.

When one wire of nearly equal resistance to that of the braid per unit of length namely # 26 B.W.G. 0.0288 ω per cm. the diameter was 0.0165" and the current required to bring it to dull redness 5.42 amp.

No. of Wire	Diam. of wire	Area	Circumf.	Surface per cm.	Res. per cm. @ 18°C	Current needed to make dull red	Activity needed per cm. watts	Activity per sq. cm.	
1	0.005" 0127	1.2668 ×10⁻⁴	0.0399	0.0399	0.3084 ω	1.33	0.709	1.77	single wire
2	0.031" 0.0787	12.864 ×10⁻⁴	0.2474	0.2474	0.0239	7.3	1.273	5.15	braid
3	0.020" 0.0508	2.027 ×10⁻³	0.1596	0.1596	0.01144	7.51	1.08	6.77	single wire
4	0.0165"				0.0288	5.42			" "
5									

On the energy lost in an iron wire armature by eddy currents in the insulated iron wires.

Let R be the radius of the wire supposed insulated.
Also assume that the magnetic flux is parallel to the axis of every wire and uniformly distributed among them.
Then consider the cross section of the armature of breadth B and depth D, made up of insulated round iron wires.
Take any one wire and a length δl of it. The lines of eddy flow will be concentric circles. Let $\dot{\Phi}$ be the time rate of flux variation, then in an elementary cylinder of radii r and $r+\delta r$, the instantaneous E.M.F. will be $\pi r^2 \dot{\Phi}$

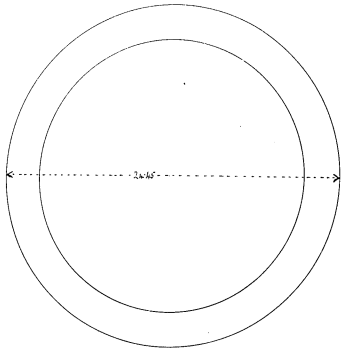
- resistance will be $\rho 2\pi r / \delta l\, \delta r$
- instantaneous current $\dfrac{\pi r^2 \dot{\Phi}\, \delta l\, \delta r}{2\pi r \rho} = \dfrac{r \dot{\Phi}\, \delta l\, \delta r}{2\rho}$
- activity $= \dfrac{\pi r^2 \dot{\Phi}^2\, \delta l\, \delta r}{2\rho}$

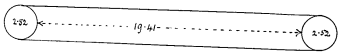
Integrating this expression from $r = 0$ to $r = R$

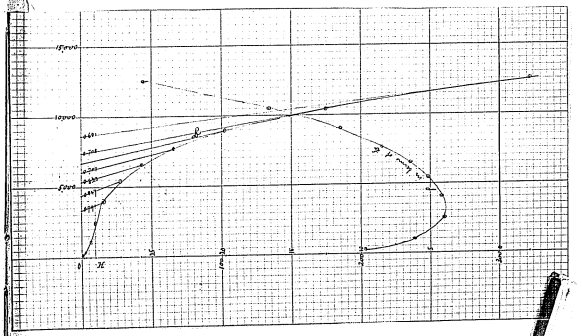
activity in δl of the wire $= \dfrac{\pi \dot{\Phi}^2 \delta l}{2\rho} \int_0^R r^3 \delta r = \dfrac{\pi \dot{\Phi}^2 \delta l R^4}{2\rho \cdot 4} = \dfrac{\pi R^2 \dot{\Phi}^2 \pi R^2 \delta l}{8\rho}$

In the section of the armature BD there will be $\frac{BD}{R^2}$ wires so that the activity in the whole armature of length δl is $\frac{\delta \pi R^2 \dot{\Phi}^2 \pi R^2 \delta l}{8\rho}$
$= \dfrac{SA\dot{\Phi}^2 \delta l}{8\rho}$ where S is the cross section of the armature and A is the area of the wire.
The total activity in the entire armature will be $= \dfrac{SA}{8\rho} \int_0^I \dot{\Phi}^2 \delta l$
in which $\dot{\Phi}$ must be expressed as a known function of l.

Plan and diametral section of soft iron ring) half linear dimensions







Magnetic Test of a ring of iron received from the Engineering Department and marked "soft iron" 11th Mar. 91.

The ring was wound with two secondary coils each of 50 turns and on opposite sides. Outside this there were 275 turns on the first layer and 262 turns on the second layer, 237 turns on the third layer making 774 turns in all.

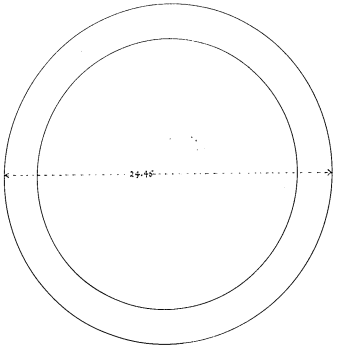
No. of Obs.	Obsd.	Amp. in	M. in AF	Log H	No. of turns	Mean throw	Resist. in ohms	R. of G. ohms	η	φ	B	μ
1	0.0225	0.1173	1.65	1.2173	5	10.2		2250	1.259×10^{6}	6.614	132.5	$\times 10^{-7}$ 12.45
2	0.0350	0.1825	2.58		5	20.6		"	2.542	1335	267.6	9.614
3	0.0490	0.2640	6.55		5	83.6		"	1.032×10^{7}	5417	1086.0	6.315
4	0.1375	0.717	10.13		5	199.4		"	2.35	12,340	2474	4.994
5	0.2305	1.202	16.98		5	53.1	25.000	30,250	6.552×10^{7}	19,820	3974	4.272 (3376)
6	0.380	1.982	27.99		5	72.4	"	"	8.934	27,030	5419	5.164 (4571)
7	0.575	2.999	42.36		5	87.3	"	"	1.077×10^{8}	32,580	6532	6.483 (5337)
8	0.8875	4.629	65.36		5	102.8	"	"	1.268	38,360	7690	8.498 (6818)
9	1.390	7.248	102.4		5	118.9	"	"	1.467	44,380	8896	11.51 (9268)
10	2.36	12.31	173.8		3	140	"	"	1.727	52,240	10,470	16.60 (13,310)
11	4.36	22.74	321.2		3	167.5	"	"	2.067	62,520	12,530	25.63 (20,540)

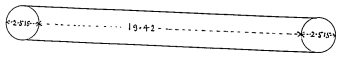
E.M.F	E.M.F	Capacity	q.	Mean throw	q. per div.
	volts				
1 B.B @ 21°	1.43114	1 F	1.4314×10^{-6}	116.0	1.234×10^{-7}

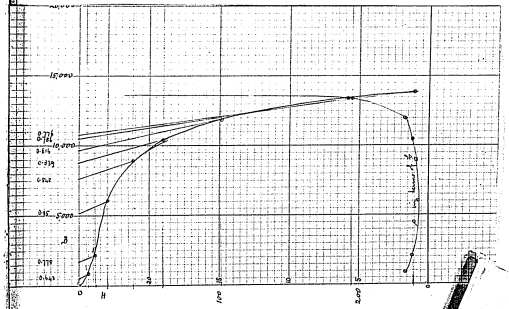
Cross sectional diameter of ring 2.52 cms.
" area " " 4.9876 sq. cms.
External diameter of ring 24.145
Internal " " " 19.141
Mean " " " 21.93
" circumference " " 68.9 cms.
Volume of ring 343.6 c.c.

Mass of ring in air 5 lbs 6 oz 4.70 grs. = 2469.14 grms
" water 4 " 11 oz 14.00 " = 2152 "
Volume of ring 317.4 c.c.
Sp. g. by dimensional volume 7.19
" " weights " 7.78

Plan and diametral section of ring) half linear dimensions







Magnetic Test of a ring of iron received from the Engineering Department and marked "best Steel" from the Eureka Cast Steel Co. Lamokin Chester Pa.

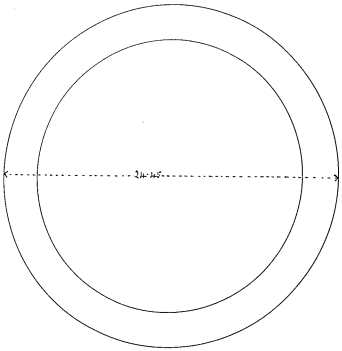
The ring was wound with 180 turns of secondary wire in two coils and oppositely situated, and above these, with 280 turns of coarse primary wire in two layers.

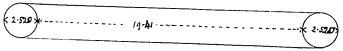
No. of known	Source of EMF	EMF	Mean Throw	Quantity	φ per div.
16	16 C.C. @ 21°C	1.4314	115.5	1.4314×10^{-7}	1.239×10^{-9}

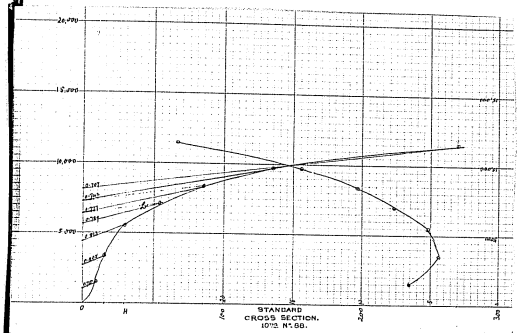
No. of Obs.	Reach	Ampères	MMF	H	No. of Throws	Mean Throw (20 Throws)	Throw in cc	A. of G. cut	q	φ	$\frac{4\pi}{A}\varphi$
			352	5.106							
1	0.2484	1.272		6.5 cm	806/816 5	616 cc	0	5250	7632×10^{-9}	4,005	1.623×10^{-3}
2	0.469	2.446		12.5 cm	2498/17911 6	167.8 "	0	-	2079 "	10,920	1.145 "
3	0.766	3.994		20.4 cm	6038/8193 6	80. "	25.000	30,250	992 "	29,990	0.680 "
4	1.422	7.508		38.34 cm	8928/7670 5	118.3 "	-	-	14.66 "	44,350	0.864 "
5	2.256	11.76		60.05 cm	10,680/7940 5	139.0 "	-	-	17.22 "	52,090	1.153 "
6	3.802	19.83		101.3 cm	11,840/9660 5	157 "	-	-	19.45 "	58,830	1.722 "
7	7.330	38.21		195.1 cm	13,370/10,810 3	177.2 "	-	-	21.95 "	66,400	3.754 "
8	9.00	46.93		239.7 cm	13,810/11,730 2	183 "	-	-	22.67 "	68,580	24.95 "

The mean diameter of ring's cross section = 2.515 cms.
" area " " " " = 4.968 sq. cms
external diameter " " = 24.48 cms
internal " " " = 19.42 "
Mean " " " = 21.935 "
" circumference " " = 68.92 "
Volume of ring from dimensions = 342.4 cc.
weight in air 86 oz 960 grs. = 2500 grs
" water 76 " " = 2155 "
volume of ring from weight = 345 c.c.
Sp. g. from dimensional volume = 7.302
" " weighing " = 7.244
Mean sp. g. = 7.273

Plan and Diametral Section of ring half linear dimensions







Magnetic test of a ring of iron received from the Engineering Department and marked "Hard Iron" from James Moore, Brick Hill Iron Works, and 16th & Buttonwood sts Phila. P.

The ring was wound with 100 turns of secondary wire in two opposite coils, and above this 398 turns of primary wire in two layers.

No. of Obs.	Watch	Amp.	MMF	H	No. of Turns	Mean Diam.	Resistance	Resistance of Coil	γ	φ	$\mathfrak{B}$	ρ	$\mathfrak{L}_{mm}$
			5094	72.62		20 Inches			1.234 X 10⁸				
1	0.232	1.21		9.164	5	115.8 (23)	0	5250	1.423 X 10⁸	7530	1510	6.607 X 10⁻⁸	1890 0.75
2	0.390	2.034		14.77	4	144.6 (27)	25.000	30250	5.526 X 10⁸	16710	3350	6.444 -	2698 0.80
3	0.778	4.058		29.47	5	73.4 (13.7)	-	-	9.095 -	27510	5516	5.314 -	4456 0.80
4	1.432	7.466		54.22	5	95.3 (20.1)	-	-	1.181 X 10⁹	35720	7162	7.57 -	5862 0.79
5	2.255	11.76		85.40	5	110.9 (24.6)	-	-	1.374 -	41,560	8332	10.25 -	6672 0.77
6	3.70	19.29		140.1	3	129.6 (23.5)	-	-	1.606 -	48580	9740	11.39 -	7824 0.82
7	7.12	37.13		269.6	3	153.3 (28.0)	-	-	1.897 -	57,450	11,520	23.40 -	9258 0.79

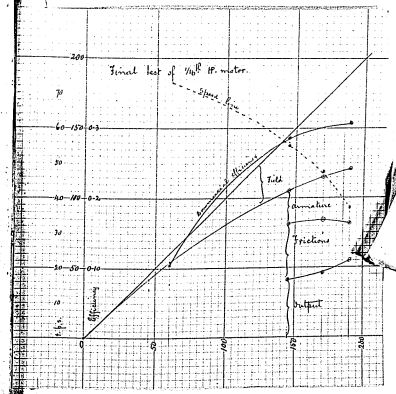
For the condenser constant of this and the following test see that given on the preceding page, which applies to these measurements.

Mean diameter of cross-section of ring 2.52 cms.
" area - - - - 4.988 sq. cms.
" external diameter - - 24.45 cms
" internal - - - - 19.41 -
" — - - - 21.93 -
" — circumference - - 68.9 -
Volume of ring from dimensions 343.7 c.c.
Weight of ring in air 1 Deg 18 deg F 2502 gms
" - - water 75 200 2145 gms
Volume - - from weights 357 -
Sp. g. of ring from dimensions 7.28 -
" " " weights 7.01
Mean 7.145

Repetition of test of Soft Cast steel ring from Schenectady.
The ring was wound with 100 turns of secondary wire in two opposite coils, and this was overlaid with 329 turns of primary wire in two layers. For the first test of this ring see p. 103.

No. of Obs.	Watch	Amp.	MMF 4π N I / 10	H 4π N I / L	No. of Turns	Mean Diam.	Res. in Ckt.	Res. of Coil	γ	φ	$\mathfrak{B}$	ρ	$\mathfrak{L}_{mm}$
1	0.237	1.236	1033.6	7.692	5	169.6 (33.2)	25.000	30,250	2.102 X 10⁸	63580	8,776	0.88 X 10⁻⁸	7.566 0.82
2	0.566	2.951		18.37	6	243.6 (47.6)	-	-	3.019 -	91320	12,600	1.458 -	10,430 0.85
3	1.238	11.67		72.64	5	166.9 (32.6)	50.000	55250	2.067 -	112,200	15,760	4.61 -	13,300 0.774
4	3.77	19.65		122.3	5	177.6 (34.8)	-	-	2.201 -	132,600	16,780	7.29 -	13,870 0.73
5	7.55	39.36		245.0	3	194 (37.3)	-	-	2.404 -	132,800	15,350	13.37 -	13,280 0.735

P.D. on mains	Clock	Current Ammeter	Activity in watts	Amperes lines in field	rpms	Drop in field	Energy in field	Energy in armt.	Drop in armt.	Energy spent in armt.	effcnt	Speed rpm
121.0	0.072	0.375	45.4	1125	1414	10.46	3.9	21.0	5.8	2.2	19.8	3520
121.0	0.095	0.496	60.0	1488	1870	13.84	6.9	17.2	7.6	3.8	13.4	1795
124.50	0.230	1.20	145.2	3600	4552.0	33.5	40.2	105.0	18.5	22.2	82.8	3325
120.75	0.270	1.405	170.1	4226	5308	39.3	55.3	114.8	21.7	30.5	84.3	2865
120.25	0.303	1.580	190.0	4740	5957	44.1	69.7	120.3	24.3	38.4	81.9	2210
120.0	0.295	1.538	184.6	4614	5800	42.9	166.0	118.6	23.7	36.5	82.1	2215



Magnetic Test of #2 D.C. Edison Motor 13. E. 91.

Two turns of wire were taken round the base of the magnets. 1st on the end where the iron idler frame projects about 4", and 2nd on the end - - - - - only. 2".

No. of Obs.	Ohms	Current in field	Turns around magnet	No. of Turns	Mean Diam	$\frac{\pi}{4}$ for Dia	Q	Rim ret	R. of ret	φ	B	ν
1	0.314	1.773	5	4	1.74	1.231×10^{-3}	2.156×10^{-3}	108,000	115,250	4.524×10^{-5}	10,560	1.26
2	-	-	5	4	1.73	-	2.114×10^{-3}	-	-	4.511 -	10,500	

At this strength of current in the fields 2.1 % of the flux is lost in leakage.

Efficiency test of the 1/16 HP. motor before sending it to Newyork.

The motor was mounted in the dynamometer self exciting and coupled to the 1/8 H.P. c.c. with the following results.

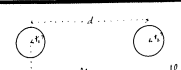
Field Strength	Speed rpm.	EMF per cm per sec.	Balance Strength	Moment	Gibs moment	Delivering watts	Friction	Electrical efficiency	Commercial efficiency	Load	Volts at comm.
.0	1400	1120	0.95					18.1	0		diac.	114
.5	1712	2975	1.25	50	7.0	350	2.158×10^{-5}	6.42	7.0		0.107	Apm light	112
.25	1995	5546	1.25	"	24.5	1225	7.55 "	41.8	41.0		0.287	S.E.F	90.3
.65	1971	4775	1.25	"	31.1	1550	9.556 "	45.6	28.7		0.268	2 λ min	82.5
.10	1830	2683	1.417	"	19.0	2445	15.08 "	55.5	26.4		0.292	1 λ	75.0
.45	1992	2742	1.42	"	49.0	2445	15.08 "	56.4	26.7		0.305	1 λ	72.8

Weight of motor with fan 15 lbs
without - 14 - 2 oz.

With 9Ω resistance in circuit of 112 v. the fan speed is about 600 rpm. The machine was connected with a sewing machine by a small rope belt and the sewing machine was operated up to about 700 r.p.m. There was abundance of power, the motor running very rapidly. When the resistance was in circuit, the sewing machine ran at slow speed. If the motor was prevented from turning, with the resistance in circuit, the motor resistance wire became rather too warm. The diameter of this wire is 0.011" (Brit g.s.). The field is wound with silk covered wire, there being no s.c.c. wire of the size in stock.

Res: of armature cool 11.22 hot 15.4
field - 25.45 - 27.9
resistance - 113.8 - 116.
153.47 159.3

Inductance of field with armature in place + field current 3.13 H.



If r_1 r_2 are the radii of two infinitely long horizontal and parallel wires
d be their centre distances apart
h " common height from the ground

Their mutual capacity in cms per cm is

$$k = 2\log_e \frac{\sqrt{d^2+4h^2}}{d} \div \mu\left\{\log_e\frac{2h}{r_1}\times\log_e\frac{2h}{r_2} - \left(\log_e\frac{\sqrt{d^2+4h^2}}{d}\right)^2\right\}\Big/\log_{10}$$

Their mutual inductance in cms per cm is

$$\mu = \log_e\left(\frac{d^2+4h^2}{d^2}\right)$$

With $d = 0.5''$ $= 1.25$
$r_1 = r_2 = 0.1'' = 0.25$
$h = 100$

$$k = 2\times 2.3026 \times \log\frac{2\times 100}{1.25} = 4.6052 \times \log 160 = 4.6052 \times 3.204112 = 14.76$$

$$\div (2.3026 \log\frac{2\times 100}{0.25})^2 - (\log 160\times 2.3026)^2 \div \mu$$

$$(2.3026 \log 800)^2 - \frac{(14.76}{4})^2 \div \mu$$

$$(2.3026\times 3.90309)^2 - \frac{(14.76}{4})^2 = (8.988)^2 - (7.38)^2 = 80.78 - 54.46$$

$$= \frac{14.76}{26.32} = \frac{0.5607}{4} \text{ cms per cm} \rightarrow \frac{0.5607}{4\pi\times 9\times 10^{20}} \times 10^{12} = \frac{0.0623}{4}\times 10^{-8} = \frac{0.0623\times 10^{-7}\times 1.649\times 10^{7}}{4} = \frac{10.2\times 10^{-8}}{4} = \frac{0.1021}{4}$$

$$\mu = 2.3026 \log\frac{4\times 10^6}{1.5625} = 2.3026 \log 2.56\times 10^6 = 2.3026\times 6.4052 = 14.75 \text{ cms per cm.}$$

$$\frac{\mu}{k} = \frac{14.75\times 10^4\times 4}{6.23\times 10^{-22}} = 4\times 2.368\times 10^{22} \qquad \frac{2\mu}{K} = 1.874\times 10^{23}$$

Calculation of ω_2 res. of two telephones $= 1.50\times 10^{11}$
inductance " " $= 1.80\times 10^{9}$

$$\text{Let } n = 1000 \quad \therefore 2\pi n = 12.42\&6.32 = 1.243\times 10^3\times 2 = 2.486\times 10^3 = p$$

$$\omega_2 = \sqrt{(1.50)^2\times 10^{22} + 2(1.243\times 1.8)^2\times 10^{22}}$$

$$\omega_1 = \sqrt{(2.25 + 2(2.074))10^{22}} = \sqrt{22.29}\times 10^{11} = 4.720\times 10^{11}$$

$$\frac{2\mu}{k\omega_1} = \frac{2\times 0.0837\times 10^{23}}{4.720\times 10^{11}} = \frac{4.914\times 10^{23}}{4.720\times 10^{11}} = 0.1400\times 10^{12} = 1400\,\omega$$

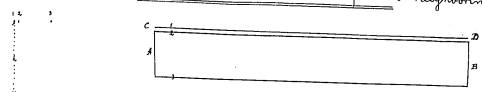
Calculation of ω_1 Bell Telephone Manufg. Co. 80 ω = 1.14 H : 1.80 × 10^10 and 1.6 × 10^7
500 0.2 H

$$2\pi n = 1.243\times 10^3$$

$$\omega_1 = \sqrt{(1.8)^2\times 10^{22} + (2.486\times 1.6)^2\times 10^{22}}$$

$$= 2\sqrt{1.69 + 3.95.7}\times 10^{11} = 2\sqrt{397.4}\times 10^{11} = 4.0\times 10^{12}$$

A problem in Telephonic induction between neighboring wires



Three wires are erected parallel and horizontal at an elevation h above the ground. The common radius of the wires is r. The distance between 1 and 2 is d. That between 1 & 3 D where D is so large relatively to d that its electrical influence upon 1 & 2 may be neglected. Then two cases are considered.

1st a simple harmonic emf e is impressed upon 1, with its distant end free, the other side of the emf being grounded, and telephones are inserted in A & B. The emf has a frequency $p = 2\pi n$, and a maximum value E. The telephone at A & B have a resistance α apiece and an inductance λ. Electrostatic currents are established in these telephone. 2 and 3 is grounded and C is the transmitting end. The periodic emf will now send a current i through CD. Neglecting electrostatic action, what must be the impedance of the circuit CD in order that the sounds in the telephones may have the same loudness as in the previous case, the resistance of the loop AB being disregarded in comparison with 2λ.

Case 1. Let k be the mutual electrostatic capacity of L_1 and L_2 [per cm. abs. measure]
$e = E\sin pt$
Then if q = the charge induced on L_2 [per cm. abs. measure]
$q = kv$ c

The current in each of the telephones $i = \frac{1}{2}\frac{dq}{dt} = \frac{k}{2}\frac{de}{dt}$

Let ζ_1 = the [current in the source] in the telephone (in arbitrary) units
Then $\zeta_1 = a\frac{di}{dt}$ where a is a constant

$$\therefore \zeta_1 = \frac{ak}{2}\frac{d^2e}{dt^2} = \frac{ak}{2}p^2E\sin pt.$$

Case 2 Let μ = the mutual inductance of L_1 & L_2
Then if ρ_2 = " impedance of L_1 abs. units
and α_1 = " " $L_2 + L_3$ abs. units

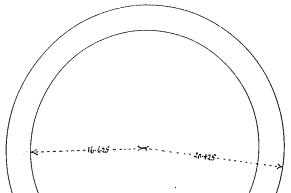
$$\gamma_2 = \frac{E\sin pt}{\omega_1\omega_2} = \frac{E\sin pt}{\omega_1\omega_2}$$

$$\zeta_2 = \frac{d\gamma_2}{dt}\frac{E\,p^2\sin pt}{\omega_1\omega_2}$$

For $\zeta_1 = \zeta_2$

$$\omega_1 = \frac{2\alpha\sin pt\, E\,p^2\sin pt}{\omega_2\, d\,kp^2\, E\sin pt} = \frac{2}{k}\frac{\mu}{\omega_2}$$

Plan and Diametral Section of Standard Wooden Ring 1/4 Size
Made of 12 pieces of wood glued together.



		ft	2πr
Mean internal radius		16.645	104.58
" external	"	20.425	128.34
"	"	18.035	113.32
" diameter of core in plane of ring			3.78
" " " plane of axis			3.89

Weight of ring 560 grms.

The figure obtained by a cross section of the core is not by any means accurately circular. A fair approximation may be to call it an ellipse of diameters 3.78 and 3.89 respectively.
Its area on the assumption of being a circle of diam: 3.78 = 11.222
" " " " " " 3.89 11.885
an ellipse 11.55

The volume on this assumption is 6544 c.c.

Adding the diameter of the wire to the diameter of the core viz 0.0432
the total diameter becomes 3.7855 + 0.0432 = 3.8287
The area of a strip on the outside of the wood = 0.0216 = 11.99 × 2.16 × 10⁻³ sq ft
This will increase the effective area to 11.8069

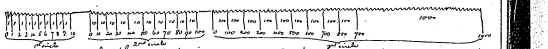
On the best dimensions of a standard wooden ring for use in measurements of magnetic permeability.

The ordinary rings of iron are 1" in diameter of core and we may reach as high a value as 2000 with them. If the standard number of turns employed on an iron ring be 25 then if the area of the standard wooden one be double that of the iron one we need 25,000 turns of wire to obtain the same thing. With a ring 13" in int: diameter and #31 copper wire covered to 0.013" there is room for 3000 turns The diameter of the wooden core may be 1.5"

The internal circumference as actually constructed had dia 1.2" The wire selected is # 28 BWG 0.014" d.c.c. to 0.017". There will be room for 2000 turns very easily. The length of each turn will be 0.393' = 786' in all say 800 in round number. The resistance of all the turns in series will be 40 ω. coil

There are three dials on the apparatus

No.1	register	0 1, 2, 3, 4, 5, 6, 7, 8, 9, +10
" 2	"	0 10, 20, 30, 40, 50, 60, 70, 80, 90, +100
" 3	"	0 100, 200, 300, 400 500, 600, 700, 800, 900, and 1000 more
		Total 2010.



The resistances of the sections are

10 turns	0.285 ω
100 "	2.295 ω
900 "	20.045 ω
1900 "	42.515 ω
2010 "	44.015 ω

The primary is wound in three layers as follows:-

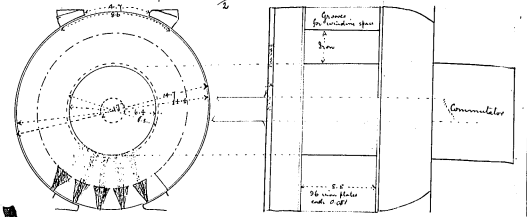
1st layer	360 turns.	diameter over wire	1 7/16"	Res @ 9°C 0.262 ω
2nd "	3444 "	" " "	2 "	" " " 0.295 ω
3rd "	338 "	" " "	2 1/8 "	" " " 0.297 ω
Total	1042 "	" " "		" " " 0.8544 ω

		MMF	H	B per sq. inch	B per sq. cm.
The MMF for the	1st layer per amp =	4π 360	H = 3.998	46.18	47.20
" " "	2nd " " =	4π 3444	3.820	44.12	45.10
" " "	1st + 2nd " =	8π 5804	7.818	90.3	92.30
" " "	3rd " " =	4π 338	3.753	43.35	44.31
" " "	1st 2nd 3rd " =	13112	11.57	133.63	136.60

The figures in the last column include the area of the wire.

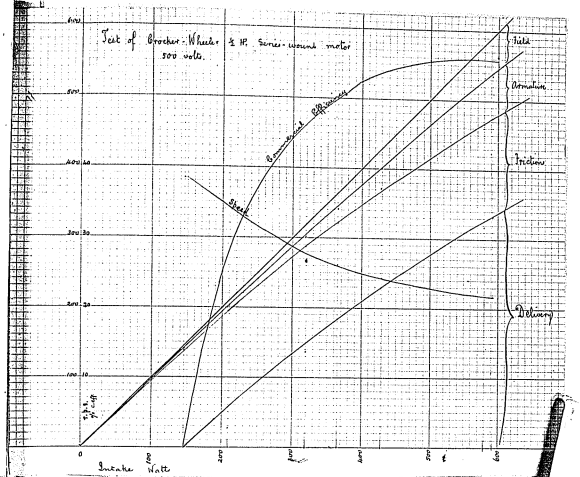
Cross Sections of Armature across and along axis

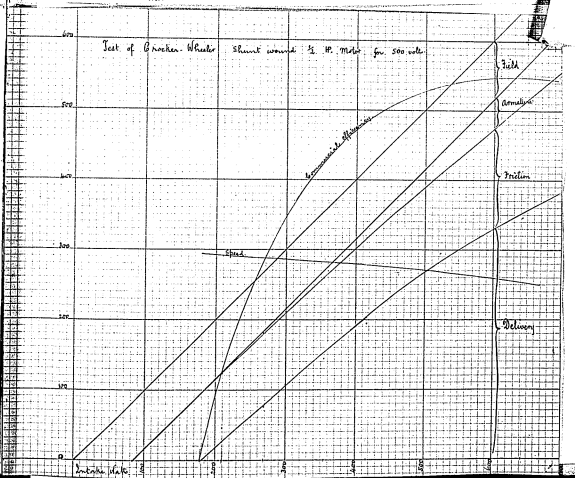
½



Test No.	P.D. at m.t.	Watts	Amperes	Energy in motor	Rev. of field	Drop in field	Energy in field	Energy in arm.	Rev. of arm.	Drop in arm.	EMF of arm.	effect
1	482	0·058	0·303	146	34·46	10·44	3·16	143·8	40·0 ~~39·67~~	12·1	459·5	139
2	"	0·083	0·433	209	34·9	15·4	6·5	192·5		17·3	449·6	195
3	"	0·127	0·662	319	35·4	23·4	15·5	303·5		26·5	432·1	286
4	"	0·145	0·756	365	35·9	27·2	20·5	344·5		30·2	424·6	321
5	"	0·170	0·887	428	36·4	32·3	28·6	399·4		35·5	417·9	371
6	"	0·235	1·226	591	36·9	46·2	55·5	535·5		49·0	387·8	475·5
7	"	0·230	1·20	578	37·4	46·9	52·8	525·2	40·5	48·0	389·1	467

Test No.	P.D. at m.t.	Watts	Current amp.	Energy in motor	Energy in arm.	Rev. of arm.	Drop in arm.	Energy of arm.	E.M.F. of arm.	effect	Speed r.p.m.	effect of arm.	Current arm.
1	492	0·032	0·167	82·2		37·7							0
2	492	0·069	0·3587	177	94·8	"	7·3	1·4	484·7	93·4	1756	2·9·3	0·193
3	490	0·080	0·417	208·5	126·3	38·1	9·5	2·4	490·5	122·9	1840	2·9·0	0·25
4	490	0·105	0·547	268·1	195·9	38·5	14·6	5·6	475·4	180·3	1720	2·8·67	0·38
5	502	0·115	0·595	300	217·8	39·9	16·8	7·3	468·2	210·9	1730	2·8·83	0·425
6	502	0·135	0·7036	353·3	271·1	39·3	21·1	11·3	480·9	259·8	1720	2·8·67	0·566
7	502	0·159	0·8283	416·3	334·1	39·9	24·3	17·14	475·7	314·7	1670	2·7·83	0·6619
8	502	0·200	1·043	523·7	441·15	39·9	35·0	30·7	467·0	410·8	1565	2·6·1	0·876
9	502	0·245	1·277	641·1	559·9	40·29	46·6	49·5	457·4	509·4	1515	2·5·25	1·110





Tests of Crocker-Wheeler 500-volt ½ H.P. Motors.

Two of these motors were received from the Edison General Electric Co. One was a series wound motor the other a shunt wound motor with a starting rheostat. The armatures on both machines seemed to be similar, as also the field frames, the only difference being in the field coils.

The armature has 24 sections like the commutator, each section being wound in a triangular groove, grammme ring fashion. The diameter of the wire is 0·0155" # 26 B&S. with 200 turns per section = 4800 wires all round. The cross section of the core is 5·5×2·40 = 13·2 sq. cms. reduced to 12·0 sq. cms by paper insulation between plates.

The entrefer is about 0·15 the mean polar arc of embrace 16·5 cms reduced by grooves to about 11·5 cms. The polar area is thus about 63·25 sq. cms.

The pole is cut away circularly, between the limits shown.

The core of the magnets is wrought iron and has a diameter of 5·4 or an area of 22·9 sq. cms. The wire on the series wound machine is # 20 B&S = 0·0319" D.C.C. & 0·0385". Its res: on both spools (cold) is 3·4. 1460 = 17·230 per spool = 1770 and the mean diameter is 3·33" circ: = 10·48" = 0·67' = 1950 turns = 80 turns per layer × 24 layers.

The weight of the shunt wound machine with pulley complete 103lb
" " " armature 2·1 lbs. 9 ½ oz. 107-

The resistance of the field of the shunt wound machine is 3140Ω cold and 3680Ω hot, a ratio of increase of 1·172 equivalent to a rise of about 44·3° C.

Speed r.p.m	r.p.s.	EMF from rev. per sec.	Balance	Moment	6165 × Moment	Energy delivered	Friction	Mech. eff.	Elect. eff.	Load	Terminal volts	
2300	38·3	12·0						139		0·954	light	11·25
2080	34·7	12·96	250 @ 5"	1250	7·709×10⁶	26·8	168·2	0·128	0·933	top arm:		·27
1610	26·8	16·12	" @ 33·5"	8374	5·163×10⁷	138·4	147·6	0·434	0·897	in S.E.F.		·30
1570	26·2	16·2	" @ 45·5"	11370	7·01 × "	183·7	137·3	0·573	0·881	bent		·37
1450	24·2	17·27	" @ 61·5"	15370	9·47× "	229·2	141·8	0·535	0·867	"		·39
1300	21·7	17·87	250/500 @ 59/0	24,750	15·26 × "	331·6	144·4	0·560	0·805	"		·45
1245	20·8	18·7	" "	"	"	317·4	149·6	0·529	0·807	"		·55

EMF per r.p.s.	Balance	Moment	6165 × Moment	Energy delivered	Friction	Mech. eff.	Elect. eff.	Load	Terminal volts	
								field	14·50	
16·55	"				93·4	0·0	0·985	running	"	
16·92	250 @ 0	2500	1·542 × 10⁷	45·2	77·7	0·217		driving	15·26	352,400
16·58	250 @ 17·0	4250	2·620 "	75·1	105·2	0·280		S.E.F	14·0	in 14,680
16·73	" @ 24·5	6125	3·776 "	108·7	101·8	0·362		1 λ	14·2	
16·77	" @ 32·5	8,125	5·010 "	143·6	116·2	0·407		2 λ	14·6	
17·10	" @ 45·5	11,375	7·012 "	195·1	121·6	0·464		3 λ		
17·9	" @ 73·5	18,375	11·33 "	295·7	115·1	0·485		5 λ	15·0	
19·1	" @ 89·0	22,250	13·72 "	346·6	163·0	0·540	+910	7 λ	16·15	

Shunt Motor

Calibration of an Alternating Current Ammeter for Clinton Preston No 4. 24th March 91.

The Siemens dynamometer compared with the Clouds gave the following

No of obs	Clouds	Siemens deflection	Decimally	Sq: root	Mean /	Clouds	Ampère	·	Accepted results	Value in °
1	1·63	90°	90.	9·487						1·258°
2	1·63	91°·30′	91·5	9·566	9·531	1·63	8·5	0·8918		5·0°
3	1·63	91°·0	91·	9·539						11·3°
4	1·149	76°·20′	76·3	8·735						20·1°
5	1·149	75°·30′	75·5	8·689	8·712	1·149	7·77	0·8918	0·892	31·4°
6	1·563	85°·50′	85·83	9·264					reciprocal 1·121	45·2°
7	1·56	82°·20′	82·6	9·088	9·176	1·562	9·1444	0·8975	1·258 recip: of reciprocal	61·5°
8	0·975	34°·0	34·	5·831	5·831	0·975	5·085	0·872		80·4°

The radius of the pointer to the scale centre is 12·4 cms.
The coil consisted of three layers of # copper wire. Two more layers were added making 5 in all. A mica vane supported on an aluminium arm was fixed to move in a brass box so as to act as a damper.

The deflections given in the last column were marked off on the scale. The distances in chordal length travelled by the pointer referred to the mean radius of the scale are

1 amp 0·82 , 2 amp 1·93 , 3 amp 3·17, 4 amp 4·66, 5 amp 5·86 , 6 amp 6·78, 7 amp 7·44.

The res: of the ammeter is 0·058 ω. Its inductance at zero 0·148 ω. at full load 0·758 ω

The calibration was effected with a current from the Siemens type alternator making 1780 rpm = 118 ~.

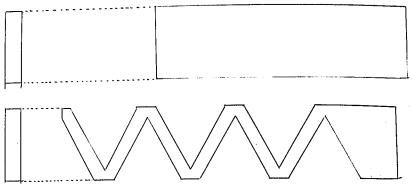
Telephone experiment 21st Mar. 91. 21 rd.

Took a small set of four magnet coils mounted on a revolving frame, and operated by a cord from the pulley of the BW arc ½ H.P. motor. At about 1500 rpm by estimation a clear note unaccompanied by any grating or other noise was heard in a distant telephone when a short length of its circuit say 4 cms long was held in front of one quadrant of the magnet frames so that the lines of force would cut it four times each revolution. The difficulty found was in attaining a sufficiently high steady speed.

On using a telephone in shunt on the a coil in circuit with one lamp, a loud note was heard in the telephone. This note was identified with M: S^{ol} of 1280 ~. There are 58 divs. in a # 12 Edison commutator and the speed is 1300 rpm. so that there would be 75,400 divs passed over per minute = 1257 ~ per second. On repeating the note in the telephone more carefully it was found to be at the #5 of $M.^{ol}$ with 1238 ~.

This sound could be heard inductively in a 50' length of green cord when some 4 ampère passed thro' the primary wire

Plan and section of one pair of carbons half size.



Arc Lighting Test. Commenced 23rd March 91.

A box of sample carbons was received from Mr Winslow Allderdice of Warren Ohio. These carbons were of special form and dimensions devised with the view of lasting 15 or 16 hours. The upper or + carbon is in the form of a strip; the lower carbon is zigzag. The dimensions of these carbons are shewn on the opposite page. They were set up on the 120 volt circuit with a lamp burning in series, and in a Wood lamp. The current required is about 10.0 amp. to produce a good arc.

The first pair marked #2 + 1 from the Faraday Carbon Co. of Pittsburg Pa. lasted 16 hours. The light was good but the arc was not always regular on the zigzag because the negative carbon did not wear level.

A second pair #3 from the Washington Carbon Co. of Washington. Weight of flat plate 117.5 grms, of zigzag 87.5g. Lasted 15 hours

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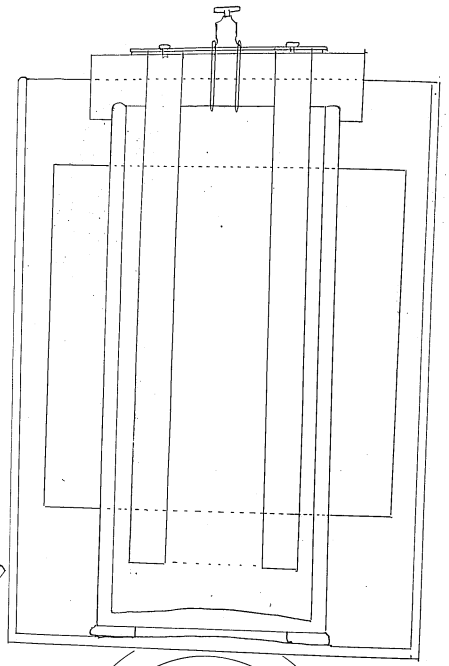
Measurement of the resistance and diameters of some copper wire stripped from a small induction coil – Medical – at the Phonograph Works. 23rd Mar. 91.

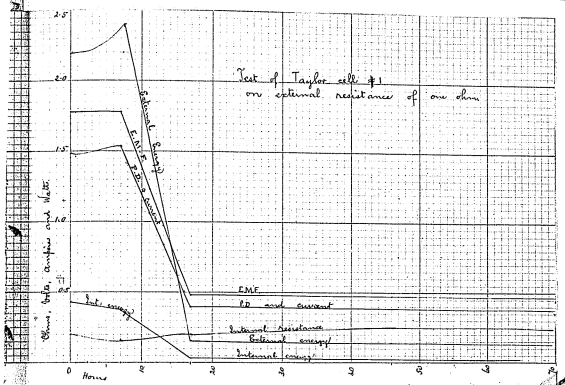
		Primary	Secondary
Diameter bare		0.0228"	0.00795"
"	covered	3.c.c 0.032"	0.012" S.c.c.
gauge Number		23 B&S.	32 B&S.
Resistance @ 18°C		1.961 ω	122.6 ω
Feet per ohm		49.35	6.122
Length – feet		96.8'	750.4'
Ohms per ohm		0.0761	1.171×10^{-3}
Weight		0.1142 lb.	0.1435 lb.

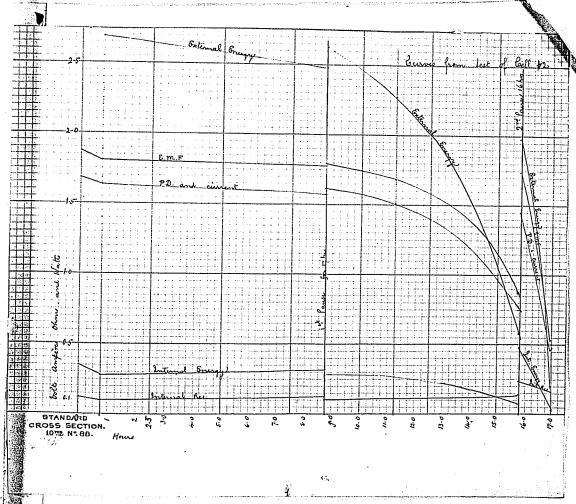
Full sized vertical section of Taylor cell with plan views of zinc and carbons.



Plan of zinc plate

Inverted plan of carbons and holder





STANDARD CROSS SECTION. 10"x 11".60.

Test of 2 cells of Taylor battery 24th March 1891.

The dimensions of these cells appear on the opposite page. This cell is cheap to manufacture. Its negative element is carbon in the form of bow ½" carbon rods. 6½" long as used in arc lamps. The positive element is zinc in the form of a plate bent circularly to conform with the jar, and heavily amalgamated. It rests on a pair of copper hooks which are not insulated in any way.

Time	Hours from start	Cell No 1. EMF	P.D.	Current	Resistance	R. of cell	Energy per unit Watts	Energy per unit watts	Cell No 2. EMF	P.D.	Current	Resistance	R. of cell	Energy per unit watts
10.30	0	1.772	1.480	1.480	1Ω	0.2	2.19	0.446	1.772	1.492	1.492	2.22	0.19	0.144
10.45	0.75	1.768	1.460	1.460	1	0.2	2.13	0.443	1.732	1.460	1.460	2.13	0.19	0.143
12.05	2.5	1.768	1.492	1.492	"	0.185	2.22	0.461	1.748	1.484	1.484	2.2	0.18	0.140
3.30	7.0	1.720	1.540	1.540	"	0.156	2.37	0.37	1.792	1.480	1.480	2.19	0.21	0.146
4.30	8.0	0.480	0.400	0.400	"	0.20	0.16	0.032	0.510	0.432	0.432	0.187	0.18	0.014
10.30	16.0	0.472	0.371	0.378	"	0.25	0.14	0.035	0.474	0.392	0.392	0.154	0.21	0.032
11.20	17.0	0.440	0.356	0.356	"	0.24	0.13	0.031	0.444	0.372	0.372	0.139	0.19	0.027

The cells were set to work independently upon a resistance of one ohm of platinoid wire.

A second test was commenced on the 1st April with new solution but without reamalgamating the zinc.

No of Cell	Date	Time	Hrs from start	EMF	PD	Current	Resistance	R. of cell	Batt. Energy	Unit Energy	Drop in cell volts	EMF	PD	Current	Drop	R. of cell	Batt. Energy	Unit Energy
1	Apr. 1st	12.0	0	1.890	1.608	1.608	1Ω	0.175	2.586	0.452	0.282	1.870	1.640	1.640	0.230	0.140	2.690	0.377
2	2nd	8.50	0	1.678	1.630	1.630	1	0.152	2.657	0.404	0.248	1.874	1.682	1.682	0.192	0.114	2.829	0.356
3		9.35	0.75	1.826	1.618	1.618	"	0.129	2.618	0.338	0.208	1.810	1.640	1.640	0.170	0.104	2.692	0.280
4		17.40	8.75	1.788	1.516	1.516	"	0.157	2.394	0.375	0.242	1.776	1.574	1.574	0.202	0.128	2.477	0.317
5	3rd	10.45	9.75	1.800	1.572	1.572	"	0.145	2.471	0.358	0.228	1.792	1.620	1.620	0.174	0.107	2.624	0.281
6		12.15	11.25	1.684	1.460	1.460	"	0.153	2.132	0.326	0.224	1.682	1.508	1.508	0.176	0.117	2.268	0.265
7		17.50	16.8	0.844	0.722	0.722	"	0.197	0.521	0.103	0.142	0.854	0.752	0.752	0.102	0.136	0.566	0.077
8	4th	9.30	15.8	1.738	1.388	1.388	"	0.247	1.926	0.514	0.350	1.740	1.540	1.540	0.200	0.130	1.971	0.471
9		10.45	17.	0.590	0.466	0.466	"	0.266	0.217	0.077	0.124	0.580	0.456	0.456	0.074	0.162	0.209	0.034

Record of some tests made on the fall of pressure in the feeders of the 26th Street Edison Station.
made 25th March 1890.

In order to determine how closely the fall of pressure of in the feeder coincided with their resistance as set out & given in our tables, I set up a potentiometer in the gallery of the 26th St. Station and determined the differences of pressure between the negative bus bar and the feeding points through the pressure wires.

No. of Feeder.	Length	Cir. mils	R. per foot by tables.	Total Resistance. ohms	Amperes	Balance	Drop by calculation	Observed Drop by Potentiometer	Obs – Calc: Discrepancy
							volts	volts	
I	1370	350 + 400	2.86×10^{-5}	3.92×10^{-2}	115	$\frac{2300}{1000} = \frac{2.3}{2.1}$	4.51	3.2	−1.21
II	1800	300 + 350	3.4×10^{-5}	6.12×10^{-2}	70	$\frac{2465}{1000} = \frac{2.65}{2.70}$	4.28	3.80	−0.48
III	1180	500	2.174×10^{-5}	2.3148×10^{-2}	125	$\frac{2469}{1000} = 2.45$	2.914	3.80	+0.86
IV	1100	400	2.613×10^{-5}	2.875×10^{-2}	115	$\frac{2480}{1000} = \frac{2.47}{2.5}$	3.31	3.55	+0.24
V	550	250	4.3×10^{-5}	2.365×10^{-2}	160	$\frac{2520}{1000} = \frac{2.083}{2.0}$	3.78	4.142	+0.64
VI	1050	550	1.976×10^{-5}	2.073×10^{-2}	120	$\frac{2520}{1000} = \frac{2.733}{2.64}$	2.149	3.92	+1.43
VII	2580	450	2.415×10^{-5}	6.23×10^{-2}	85	$\frac{2540}{1000} = \frac{2.05}{2.9}$	1.844	4.23	+2.39
VIII	2320	350	3.1×10^{-5}	7.19×10^{-2}	90	$\frac{2550}{1000} = \frac{2.15}{2.1}$	6.47	3.09	−3.38
IX	820	250	4.3×10^{-5}	3.526×10^{-2}	85	$\frac{2570}{1000} = \frac{2.37}{2.46}$	3.00	3.40	+0.40
X	1400	500	2.174×10^{-5}	3.044×10^{-2}	90	$\frac{2570}{1000} = \frac{2.37}{2.42}$	2.74	3.69	+0.95
"	1'				90	$\frac{2560}{1000} = \frac{2.46}{2.62}$		4.0	
XIII	2480	350	3.1×10^{-5}	7.69×10^{-2}	65	$\frac{2520}{1000} = \frac{2.8}{2.82}$	2.15	4.0	+1.85
					65	$\frac{2500}{1000} = \frac{2.5}{2.4}$		3.59	
					70	$\frac{2500}{1000} = \frac{2.73}{2.63}$		3.92	
XII	1580	400	2.613×10^{-5}	3.928×10^{-2}	60	$\frac{2460}{1000} = \frac{2.46}{2.4}$	2.35	3.44	+1.09
XIV	1750	500	2.174×10^{-5}	3.805×10^{-2}	105	$\frac{2500}{1000} = \frac{3.7}{3.67}$	4.00	3.88	−0.12
XVIII	650	250	4.3×10^{-5}	2.794×10^{-2}	65	$\frac{2500}{1000} = 2.71$	1.82	3.92	+2.10
XIX	3350	6070 + 3200 + 1250 + 600	2.86×10^{-5} + 1.512×10^{-5}	5.92×10^{-2}	100	$\frac{2485}{1000} = \frac{2.99}{2.95}$	0.59 + 3.75 = 4.34	4.28	+1.37
XXI	2300	400	2.613×10^{-5}	6.01×10^{-2}	70	$\frac{2520}{1000} = \frac{2.73}{2.76}$	4.27	3.92	−0.35
XXIX	1350	450	2.415×10^{-5}	3.26×10^{-2}	70	$\frac{2520}{1000} = \frac{2.42}{2.5}$	2.28	3.27	+0.99
XXX	1300	450	2.415×10^{-5}	3.14×10^{-2}	78	$\frac{2500}{1000} = 3.2$	2.36	3.39	+1.03

249.0 volts across bus-bars
1240 feet of cable same size as feeder in circuit with each feeder within the limits of the building.

Sum of + discrepancies 15.34
− 5.54
Excess in 19 9.80
average 0.54 volts more drop observed than ought to exist.

110 divs × 6·25 = 6875 divs: thro: 301,000 ω 1 cell.

50 Aybll. charging 1′ give 20 × 217·7 = 4354 divs: ∫ ratio 53·75
1 " " " 81

∴ 50 Aybll. thro 301,000 ω give 6875 × 53·75 = 369,960 divs:
or 1 div: represents $369 \times 10^4 \times 3{\cdot}01 \times 10^{-1}$ megohms = $11{\cdot}13 \times 10^3$ = 11,130 Ω

$\frac{D}{d} = \frac{175}{102} = 1{\cdot}716$ $\log_e \frac{D}{d} = 0{\cdot}54$ $0{\cdot}075 \times 0{\cdot}54$

$\frac{V}{v} = \frac{320}{306} = 1{\cdot}046$ $\log 1{\cdot}046 = 0{\cdot}019153 \times 2{\cdot}303 = 0{\cdot}044498$

$70 \div (0{\cdot}044498 \times 0{\cdot}075) = 70/4{\cdot}4498 \times 10^{-3} = 70/3{\cdot}374 \times 10^{-3}$
$= 20{\cdot}75 \times 10^3 = 20{,}750\ \Omega$

$\frac{V}{v} = \frac{266{\cdot}5}{231{\cdot}5} = 1{\cdot}151$ $\log 1{\cdot}151 = 0{\cdot}060870 \times 2{\cdot}303 = 0{\cdot}1232$

$60 \div (0{\cdot}1232 \times 0{\cdot}064) = 60/7{\cdot}892 \times 10^{-3} = 60/3{\cdot}573 \times 10^{-3} = 1{\cdot}679 \times 10^4$

$\frac{V}{v} = \frac{461{\cdot}5}{397{\cdot}5} = 1{\cdot}161$ $\log 1{\cdot}161 = 0{\cdot}064591 \times 2{\cdot}303 = 0{\cdot}1748$

$60 \div (0{\cdot}1748 \times 0{\cdot}106) = 60/0{\cdot}01853 = 3240$

Telephonic experiments. 24th March. (116)

Took the 1000 feet of 4mm/m cable a test of which is given in the record for 27th February 1888.

The following tests were made of this cable, after it had been taken out of its tank, uncoiled and laid in an irregular loop round the premises on the ground.

Insulation by Direct Deflection. Constant ½ Aybll.
through 300,000 ω G. 5250 (ballistic) shunted by 1000 ω = 110 divs.
1 Aybll. charging 1′ 81 divs: 50 Aybll: charging 0·05′ 217·7 divs:

Insulation of interior wire to exterior wire by direct deflection 50 Aybll 2 ∞
1·5 divs. = 74160 Ω abs.

Insulation of exterior strand by direct deflection 50 Aybll. 2 ∞ 5 divs:
= 2226 Ω abs.

Insulation by full of charge, using 50 Aybll. cells and ballistic G.

Interior strand, with exterior grounded. Charge 320 divs:
after one minute's insulation charge (10 secs) 14 "
= 20,750 Ω

Interior strand free, exterior strand charged. Charge 266·5 divs:
after one minute of insulation charge 35 "
= 16,790 Ω

Interior strand grounded, exterior strand charged, Charge 461·5 divs
After one minute of insulation charge 14 "
= 3,2400 Ω

Capacity of inner strand to ground outer strand free 0·021′
" " " " grounded 0·075′
" " outer " " inner " free 0·029′
" " " " grounded 0·106′.

These measurements are with Gotchmuster.
The cable was dry on comparatively dry ground

Resistance of interior conductor 2·4215 ω @ abt 12° C.
" " exterior " 0·4497 ω " "

Inductance balance with secohmmeter 1000/10 2·534 ω 0·22′ interior
" " " 1000/10 0·616 ω 0·85′ exterior

No change in either balance discernible when the other strand was inserted in the battery ct. showing that the mutual inductance is negligible.

The following are the dimensions of the core :-

Inner conductor of 7 wires each 0·025"
strand diam 0·102
Diam G.P. covering 0·175
Outer conductor of 18 wire each 0·036"
Diam. over strand 0·247"
" of g.p. covering 0·370"
" of ext. binding 0·425"

Telephonic Experiments continued.

A telephone of the ordinary Bell type marked # 1144, 040 A has a resistance @ 24°C of 73 ω and an inductance of 113.4 H. It was joined across the mains with resistance inserted until the note $\frac{1300 \times 55}{60}$ = 1287 ω per sec. mentioned on page 112 just ceased to be heard. The resistance required was a coreless induction coil secondary having a resistance of 45,200 ω and an inductance of 22.6 H.

No 1. The neutral wire of the 3-wire system was now grounded, and the terminal joined to the external core through another telephone B the internal core being free. The note was heard in this telephone.

No. 2. The external strand was now grounded through telephone A. B's note was now louder. A's note was about equally loud.

No. 3. The β end of the external strand was now grounded. The note in A entirely ceased. B's note remains unaltered in strength but a higher shrill note was superposed upon it.

No. 4. The external strand was now connected through B to the dynamo, the interior strand free. B altered as a distinct note.

No. 5. The α end of the interior strand was grounded through A. Loud sounds in B and A.

No. 6. The β end of the interior strand was now grounded direct. Loud sounds in B, with a fainter shrill note superposed silence in A.

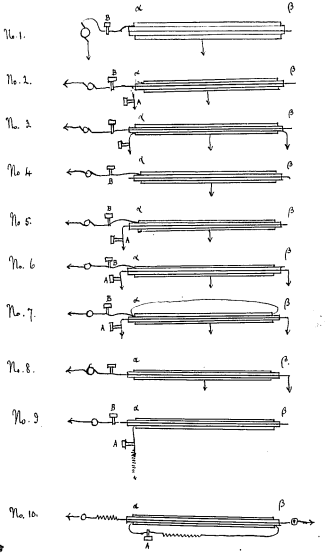
No. 7. The β and α ends of the exterior strands are directly connected without any change in the high superposed note of B.

No. 8. The dynamo was connected with the interior strands of the wire through B, the exterior strand free. Faint note in B.

No. 9. The dynamo was connected with the interior strand of the wire and the exterior grounded through A and a resistance. This resistance was increased until the sounds in A just reached the limit of clear audibility. This resistance was 314,8,000 ω with an inductance of 44·3 H = 1493,000 ω impedance to pure sine wave.

No. 10. B was now removed, and a current sent through the interior strand, graduated by a lamp bank and read with a galvanometer. The limiting conditions for electromagnetic induction

No. of Obs	Current in Mains	Primary Amperes	Sends in per cent	Rec. in per cent	Recs. in 2nd cct.	Sends in 2nd cct	Sounds in A	Comparison per cent.	Primary Freq.	Secondary Freq.
1	0·073	0·5215	–	229·7	89,000	0·113	just audible	1	240	138,000
2	0·1142	0·7140	–	168·9	110,000	0·113	–	2	169	110,000
3	0·272	1·219	–	88·1	209,000	–	–	4	88·1	209,000
4	0·500	2·608	–	47·9	409,000	–	–	9	47·9	409,000
5	0·532	2·774	4·964	45·07	110,000	–	–	9	59·7	110,000
6	0·55	2·868	37·94	43·59	29,000	–	–	12	302·5	29,000
7	0·500	2·608	–	47·9	409,000	–	–	8	47·9	409,000



$\frac{1.257^2 \times 10^6 \times 4.96^2 \times 10^{-4}}{4.507^2 \times 10^{10}} = \frac{1.580 \times 24.6}{20.313} \times 10^{-2} = 1.914 \times 10^{-2} \times \frac{4\pi^2}{4\pi^2} = 0.01914 \frac{4\pi^2}{4\pi^2} = 0.7554$

$\sqrt{1.7554} = 1.325 \times 45.07 = 59.73$

$\beta^2 = 6.24 \times 10^7 \qquad 6.24 \times 10^7 \times 37.9^2 \times 10^{-4} = 6.24 \times 14.364 \times 10^3 = 89.62 \times 10^3 = 8.962 \times 10^4$

$R^2 = 19.00 \quad ; \quad 89.620 + 19.00 = 91.520 = (302.5)^2$

$(3.143 \times 10^5)^2 = 12.11 \times 10^{10} \qquad \beta^2 = 6.24 \times 10^7 \qquad 6.24 \times 10^7 \times 4.43^2 \times 10^3 = 19.62 \times 10^8 \times 6.24$

$= 122.5 \times 10^8 = 1.225 \times 10^{10} + 1.211 \times 10^{10} = 2.436 \times 10^{10} = 24.36 \times 10^{9} = (4.93 \times \pi^2)$

$\beta^2 h^2 \nu^2 = 6.24 \times 10^7 \times (6.4)^2 \times 10^{-54} \times (3.48)^2 \times 10^{28} = 6.24 \times 5.6.25 \times 12.11 \times 11^2 = 4.252 \times 10^6$

$L \lambda \beta^2 = 4.45^2 \times 10^{14} \times 1.72 \times 10^{-17} \times 6.24 \times 10^7 = 2.471 \times 10^{-6} = (-2.06.4)^2 + 42600 + 42,520 = 9,51,20 = 84^2$

Comparison of Ammeters 27th March 1891.

As a check upon the accuracy of the results obtained with the feeders in 24th St. Station as recorded on p. 115, an ammeter from one of these feeders was by the courtesy of the Superintendent forwarded to the Laboratory for testing. Three other large ammeters from the Laboratory were tested at the same time. The feeder ammeter is marked #19 but not + or –

No of Obs.	P.D. on large Shunt leg. volts	Res. of Shunt	Current Amp.	Shunt Deft.	Current ampere	Feeder ammeter	Amm 1000 ampere	1000 ammeter #1	1000 ammeter #2	% of Feeder	% diver: from Lab.
1	0·0192	0·00162 Legt – @22°C.	38·3	7·14	37·23	33	35			5·3	13·8
2	0·088		54·33			52·5	61	50	50	1·8	3·3
3	0·192		118·5			115	115	110	110	3·5	3·0
4	0·268		165·5			160	160	150	150	5·5	3·3
5	0·278		171·6			165	165	150	150	6·6	2·9
6	0·362		223·5			217	220	205	205	6·5	2·9
7	0·442		272·9			262	262	250	260	10·9	4·0

Determination of Field Winding for the 120-140 Volt 1 H.P. Shunt Edison small motor 1st April 91.

From the results given on page 121 it is evident that we require 2000 ampere turns. With 0·30 amp this means 6700 turns of wire. The resistance hot must be $\frac{120}{0·3}$ = 400 ω. The length of the interflange is 4·425" and the core diameter 2·625". Depth of winding say 0·9" = 4·425" ext. diam. The mean diameter will thus be 3·525" = 11·08 – 0·092' 6700 × 0·092 = 6183 amp 6200' for 400 ω = 15·5' per ω @ 60°C. This is represented most nearly by # 28 + # 29 BWG, 0·014" and 0·013".

0·014" # 28 BWG = 0·026" cond. 400 ω @ 0·09866 lbs ent 16·59' = 3·94 lbs = 6640'
0·013" # 29 BWG = 0·023" – 400 ω 0·0733 – 4·31 = 2·92 = 4920'

No. 28 will be preferable. There would then be 160 turns per layer and 6800 turns = 42·6 layers = 1" depth.

Result 4 lbs. of # 28 BWG copper wire. Probably 5 lbs. of covered wire.

Meeting of the Committee on Lightning Protection appointed by the Association of Edison Companies

A meeting of this Committee took place on the 30th March 91.
Messrs W. Jackson + W. S. Howell members.

It was decided to try lightning arrestors of which samples were prepared. Two sheets of lead foil 6"×2' are laid up parallel to their width upon a sheet of paraffined paper about 0·015" thick. In this way a condenser is obtained in the form of a roll and has a capacity ranging from 0·02 μf to 0·027 μf.

One electrode is brought out in the form of a stout lead wire, serving as a safety catch to break a dynamo spark. The other is grounded through a copper wire.

The roll is inserted in a sealed zinc tube with a band for support soldered on.

On the equations of motion in a simple inductance circuit under the action of periodic impressed electromotive forces.

Assuming a periodic emf. of instantaneous value e, r a constant inductance we have $e = cr + l\dot{c}$

$$\dot{c} + \frac{r}{l}c = \frac{e}{l} \quad \text{and if } \frac{r}{l} = P \;,\; \frac{e}{l} = Q \;,\; y = c, \text{ this becomes}$$

$$\frac{dy}{dx} + Py = Q \;,\; \text{a standard form of which the solution is}$$

$$y = \kappa\, \varepsilon^{-\int P dx} + \varepsilon^{-\int P dx} \int \left(Q\, \varepsilon^{\int P dx} \right) dx$$

(1) . . . . . or $c = \kappa\, \varepsilon^{-\int \frac{r}{l} dt} + \varepsilon^{-\int \frac{r}{l} dt} \int \left(\frac{e}{l}\, \varepsilon^{\int \frac{r}{l} dt} \right) dt$ Now let $e = \varphi(t)$

(2) . . . . . $c = \kappa\, \varepsilon^{-\frac{t}{\tau}} + \varepsilon^{-\frac{t}{\tau}} \frac{1}{l} \int \varphi(t)\, \varepsilon^{\frac{t}{\tau}} dt$ where $\tau = \frac{l}{r}$ . . . . . (a)

Let $e = \varphi(t) = E \sin(\omega t + \beta)$

by (2) $c = \kappa \varepsilon^{-\frac{t}{\tau}} + \varepsilon^{-\frac{t}{\tau}} \frac{E}{l} \int \varepsilon^{\frac{t}{\tau}} \sin(\omega t + \beta)\, dt.$

$$= \kappa \varepsilon^{-\frac{t}{\tau}} + \varepsilon^{-\frac{t}{\tau}} \frac{E}{l} \left[\frac{\varepsilon^{\frac{t}{\tau}} \left\{ \frac{1}{\tau} \sin(\omega t + \beta) - \omega \cos(\omega t + \beta) \right\}}{\frac{1}{\tau^2} + \omega^2} \right]$$

$$= \kappa \varepsilon^{-\frac{t}{\tau}} + \frac{E}{r} \frac{\left\{ \sin(\omega t + \beta) - \omega\tau \cos(\omega t + \beta) \right\}}{(1 + \omega^2\tau^2)}$$

$$= \kappa \varepsilon^{-\frac{t}{\tau}} + \frac{E}{r} \frac{\sin(\omega t + \beta - \tan^{-1}\omega\tau)}{\sqrt{1 + \omega^2\tau^2}}$$

Also with $c = 0$ at $t = 0$

$$c = \frac{E}{r} \frac{\sin(\omega t + \beta - \tan^{-1}\omega\tau)}{\sqrt{1 + \omega^2\tau^2}} \left(1 - \varepsilon^{-\frac{t}{\tau}} \right) \quad \text{- - - - - - - - - - - - - - (3)}$$

This is the current in a circuit subject to a simple harmonic emf.

Now let $e = \varphi(t) = E_1 \sin(\omega_1 t + \beta_1) + E_2 \sin(\omega_2 t + \beta_2) + E_3 \sin(\omega_3 t + \beta_3) + \text{&c.}$

by (2) $c = \kappa \varepsilon^{-\frac{t}{\tau}} + \varepsilon^{-\frac{t}{\tau}} \frac{1}{l} \int \left(E_1 \sin(\omega_1 t + \beta_1) \varepsilon^{\frac{t}{\tau}} + E_2 \sin(\omega_2 t + \beta_2) \varepsilon^{\frac{t}{\tau}} + \right) dt$

$$= \kappa \varepsilon^{-\frac{t}{\tau}} + \varepsilon^{-\frac{t}{\tau}} \frac{E_1}{l} \int \sin(\omega_1 t + \beta_1) \varepsilon^{\frac{t}{\tau}} dt + \varepsilon^{-\frac{t}{\tau}} \frac{E_2}{l} \int \sin(\omega_2 t + \beta_2) \varepsilon^{\frac{t}{\tau}} dt + \text{&c.}$$

$$= \kappa \varepsilon^{-\frac{t}{\tau}} + \frac{E_1}{r} \frac{\sin(\omega_1 t + \beta_1 - \tan^{-1}\omega_1\tau)}{\sqrt{1 + \omega_1^2\tau^2}} + \frac{E_2}{r} \frac{\sin(\omega_2 t + \beta_2 - \tan^{-1}\omega_2\tau)}{\sqrt{1 + \omega_2^2\tau^2}} + \text{&c.}$$

and with $c = 0$ at $t = 0$

$$c = \Sigma \left\{ \frac{E \sin(\omega t + \beta - \tan^{-1}\omega t)}{r\sqrt{1 + \omega^2\tau^2}} \right\} \left(1 - \varepsilon^{-\frac{t}{\tau}} \right)$$

No. of Obs.	Time	P.D. on motor	Obach	Ampères	Energy in motor	Res. of armature	Drop in armature	Energy in armature	Energy in arm.	Res. of field.	Drop in field.	Energy in field	Effect
1	14.30	220	0.092	0.48	105.6	20.8	10.0	4.8	104.8	3.47	1.7	0.8	100
2	14.35	244	0.123	0.64	156.2	21.	13.4	8.6	154.8	3.5	2.2	1.4	148.2
3	15.04	243.5	0.155	0.808	196.7	21.2	17.1	13.8	194.4	3.53	2.9	2.3	180.6
4	.07	244	0.204	1.064	260	21.4	22.8	24.3	256	3.56	3.8	4.0	231.7
5	.10	244	0.240	1.250	305.0	21.6	27.0	33.8	299.4	3.59	4.5	5.6	265.6
6	.15	243	0.361	1.880	457.0	21.8	41.0	77.1	444.2	3.62	6.8	12.8	367.1
7	.20	243	0.476	2.586	628.0	22.0	56.9	147.2	593.7	3.65	9.4	24.3	446.5
8	16.10	241	0.472	2.46	593.0	22.2	54.6	134.3	570.6	3.68	9.1	22.4	436.3
9	.13	242	0.540	2.816	681.6	22.2	62.5	176.0	652.3	3.70	10.4	29.3	476.3

700

PARTICULARS OF EDISON MODEL 1/2 HP. [illegible]-VOLT SERIES MOTOR.

Weight on wooden base with pulley [illegible] 37 1/2 lbs.

Winding gramme ring and series field.

Voltage at machine terminals 250.

Amperes at delivery of 400 watts. [illegible] running light 0.[illegible] amp.

Commercial efficiency at full load [illegible] %, at half load 60 %.

Speed running light 3000 r.p.m. at full load 1500 r.p.m.

Dimensions :- Armature body

External diameter 6 ". Internal 4".

grooves 42 on each side.

Breadth of armature body over teeth 1.45"

" " at base of grooves 1.0"

Depth of grooves 0.26", breadth 0.2[illegible]"

Band iron in core prepared at Schenectady Works.

Cross -Section of armature core 1.0 sq. in.

Breadth of teeth 0.1[illegible]" at external, 0.0[illegible]" at internal circle.

Polar surface of teeth [illegible] sq. cms. under each pole.

Winding [illegible]0 turns viz:- [illegible] layers of 10 turns each of #2[illegible] BWG. wire 0.014" covered [illegible] 0.023"

Commutator divs. 42. German silver connections 0.00[illegible]"

Armature groove insulation 0.01" mica at sides; 0.01" oiled silk on base.

Total weight of wire on armature [illegible] lb. length about 1560[illegible]

Resistance of armature between brushes including german-silver connections 20.[illegible] ohms cool 22.2 ohms [illegible].

Current in armature at full load 2.[illegible] amperes.

Drop in armature at full load 60 volts.

Energy expended in heating armature at full load [illegible] watts.

Magnetic flux through armature section at load 100,000 CGS.

In [illegible] density [illegible] iron [illegible], about 15,000

[illegible]

[illegible]

[illegible] ,0" [illegible]"

[illegible] "

[illegible] at full load 300,000

[illegible] core at full load [illegible],000

[illegible] BWG. [illegible] 0.0[illegible]" covered to 0.051"

[illegible] ohms hot.

[illegible] at full load 10 volts, [illegible] watts.

Re[illegible] between terminals [illegible] ohms cool [illegible] hot.

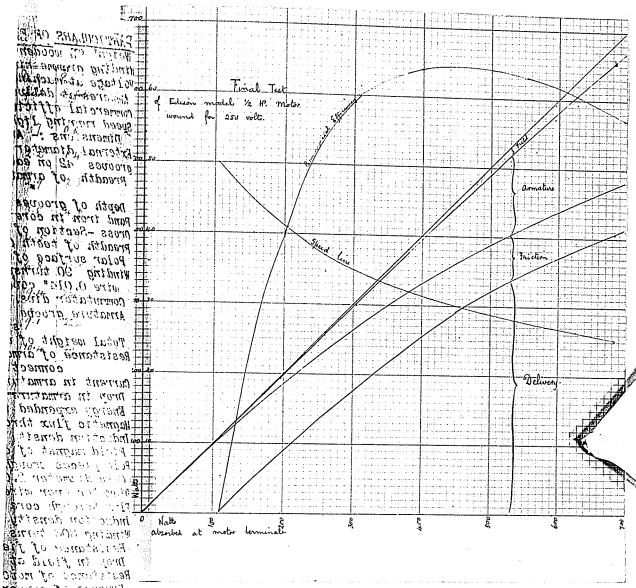
[illegible] of commutator.

[illegible]

[illegible] each.

Total weight [illegible] lbs.

Delivery of [illegible] 10.[illegible] [illegible] lb. of total weight.

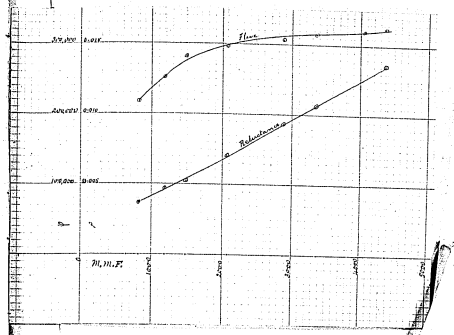

Trial Test
of Edison model ½ H.P. Motor
wound for 220 volts.
Efficiency
Input
Armature
Friction
Delivery
Watts absorbed at motor terminals

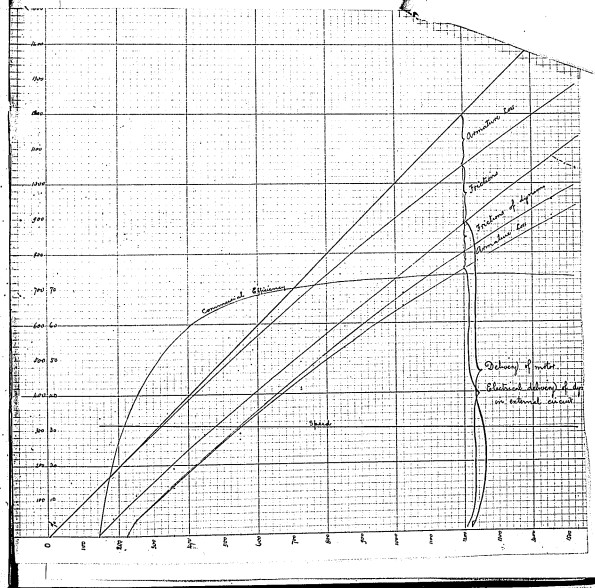
Test of the model ½ H.P. 250 volt motor series wound 27 III gn. (120

The resistance of the armature cool is 20.83 ω field 3.47 ω
" " " " hot " 22.16 " " 3.70 "
The motor was set in the large tank and balanced to diameter the 10000 ...

Speed r.p.m.	r.p.s.	E.M.F. generated	Opts. per Amp. per cent	Balance	Moment	6165 × Moment	Driving	Friction	Electrical η	Commercial η	Sound
3000	50	208.3	4.16	—	—	10'	—	—	0.947		Free
2705	45.1	228.4	5.07	250 @ 23	5750	3.946	160	—	0.936	(	Dynam
2400	40	226.8	5.67	257 @ 26	6400	3.946	158	22.6	0.932	0.893	S.E.F
2210	36.8	225.9	6.14	250 @ 37	9250	5.703	210	21.7	0.926	0.858	1 λ
2080	34.7	212.5	6.12	250 @ 45	11,250	6.936	241	24.6	0.871	0.790	2 "
1830	30.5	195.2	6.40	250 @ 23 / 500 @ 26	18,750	9.710	296	710	0.803	0.648	4 "
1580	26.3	176.7	6.72	250 @ 55 / 500 @ 20	23,750	1.464	385	61.0	0.727	0.613	6 "
1600	26.7	177.3	6.64	"	"	"	391	45.3	0.730	0.659	" "
1500	25.0	169.1	6.76	250 @ 65 / 500 @ 32	24,250	1.618	405	71.3	0.736	0.574	8 "
									Logg		

No. of Obs. Time	P.D. on m.t.	Ohmic	Current supplied M	Energy in armt.	Energy in armt.	drop volts	Energy Lost in armature	Effort	Speed of armature r.p.s.		EMF	EMF from fx.
9.50 1									0			
.57 2	123.5	0.240	1.512	1.22.0	186.7	1.8	2.7	184.	1890	31.5	121.7	3.86
10.03 3	122.8	0.325	1.851	1.25	225.7	2.3	4.3	227.4	1860	31.0	119.7	3.86
.13 4	122.5	0.390	2.034	1.25	249.2	2.6	5.3	249.9	1880	31.3	119.9	3.83
.17 5	122.0	0.562	2.921	1.31	357.6	3.8	11.1	346.5	1855	30.92	118.2	3.82
.21 6	121.5	0.705	3.677	1.34	446.7	4.9	18.0	428.7	1840	30.67	116.6	3.80
.25 7	121.0	0.705	3.677	1.37	444.9	5.0	18.4	426.5	1835	30.6	116.0	3.79
.29 8	121.5	0.670	4.537	1.40	551.3	6.14	28.8	522.5	1835	30.6	115.1	3.76
10.33 9	121.5	1.15	5.996	1.43	728.4	8.6	51.4	677.0	1815	30.25	112.9	3.73
.37 10	121.5	1.35	7.04	1.46	855.2	10.3	72.4	772.8	1770	29.5	111.2	3.77
.41 11	120	1.64	8.551	1.49	1026	12.7	109.0	917.	1765	29.42	107.3	3.65
.45 12	119	2.35	12.25	1.50	1458	18.4	225.0	1233	1750	29.12	100.6	3.46
10.49 13	119.5	2.45	12.74	1.50	1527	19.2	245.0	1282	1740	29.0	100.3	3.46





Test of 1 HP. 120-volt motor 31st March 1891

The motor has multipolar fields with laminated pole pieces made up of strips each " thick. The pole pieces are strapped to the polar extensions. There are 9 layers of 77 turns on the field magnet

No.	Lamps in field	Ampere turns	Ampere turns per inch	Amp Turns	MMF	Shunt	Ampere in armature	Drop in armature	E.M.F. G.M.T.	E.M.F. gauges	ϕ lines	$\mathcal{Z}$	ρ	Speed
1	14	0·06819	5·030	3·686	4·381	0·228	1·189	1·444	120·5	119·1	3232·X10⁶	16,160	1·35×10⁻³	1755 1925
2	10	0·51503	3·879	2·688	3·380	0·232	1·21	1·47	-	119·0	3·148 ..	12,740	1·074×10⁻³	1800 30
3	8	0·44·001	3·314	2·297	2·887	0·232	"	"	"	"	3076 ..	12·380	9·38×10⁻⁴	1820 30·7
4	6	0·31640	2·387	1·654	2·079	-	-	-	12·1	119·5	2·964 ..	11,820	7·06 "	1920 32·1
5	4	0·22629	1·704	1181	1·485	-	-	-	12·1	119·5	2·811 ..	11,060	5·28 "	2025 33·8
6	3	0·18053	1·3623	943·5	1186	0·2414	1·272	1·53	-	119·5	2·528 ..	12,620	3·169 "	2250 37·5
7	2	0·12279	0·9246	640·7	805·4	0·268	1·347	1·70	-	119·3	2·486	10,930	3·66 "	2400 40·1

The resistances of the armature between brushes cool = 1·216 Ω
across diameter cool 1·465 Ω
field cool 3·12 Ω

Efficiency test of 1 HP. 120-volt motor with its field separately excited.

Balance	Moment	Gross Moment	Declining	Friction	P.D. at brs Terms	Ring Lamps	Amperes	Brit: no of dynamo	Rheost.	Emf	Energy Power in Watts Cum.	Total
250 @ 19												
@ 27	2500	1·574×10⁴	49·6 0·340	18·55·44								
@ 36·7	4425	2·721 -	86·6 0·375	136·8								
@ 42·5	5875	3622 -	113·44 0·455	130·5	109·5	0·05533	0·1017	4·88 w	485	109·9	2·67	487
@ 54	10,000	6·165 -	190·6 0·533	158·9	108·5	0·16296	1·227		12	109·7	133·1	1364
250 @ 19 / 1000 @ 30 Send back on 2nd arm	15000	9·246 -	283·6 0·633	143·1	107·7	0·27263	2·053		24	109·8	221·1	2255
5700 @ 30	15,000	9·246 -	283 0·616	143·5	108	0·26795	2·018		24	110·1	218·	2221
2100 @ 18 / 3150 @ 30	19,450	11·99 -	367 0·666	155·5	108·5	0·36758	2·618		24	110·1	284·	291
250 @ 43·5 / 5250 @ 30	26,375	16·24 -	491·8 0·672	185·2	114	0·47341	3·565		38	117·6	406·5	449
2200 @ 30 / 3000 @ 50	32,500	20·04 -	591·2 0·69	181·6	112	0·63095	4·751		48	114·9	532·	582
5700 @ 30 / 2000 @ 64	41,000	25·28 -	744·8 0·722	163·2	109	0·79070	5·9524		60	115·	649	685
2200 @ 60 / 8000 @ 50	60,000	36·99 -	1078 1·046	155·8	116·5	1·08207	7·686		87	120·2	935·	984
2000 @ 55 / 10000 @ 50	58,250	35·92 -	1045·5 1·013	240·5	116	1·05553	7·798		58	119·8	934·	960·6

$$\frac{I}{4} = \int_a^Y \frac{dy}{y}\left\{\sqrt{X^2+y^2} - \sqrt{\alpha^2+y^2} + y\log_e\frac{\sqrt{X^2+y^2}-X}{\alpha} - y\log_e\frac{\sqrt{\alpha^2+y^2}-y}{\alpha}\right\}$$

$$\frac{I}{4} = \int_a^Y \frac{\sqrt{X^2+y^2}}{y}dy - \int_a^Y \frac{\sqrt{\alpha^2+y^2}}{y}dy + \int_a^Y \log_e\frac{\sqrt{X^2+y^2}-y}{X}dy - \int_a^Y \log_e\frac{\sqrt{\alpha^2+y^2}-y}{\alpha}dy$$

$$= \quad A \quad - B \quad + \quad C \quad - \quad D$$

$$A = \int_a^Y \frac{\sqrt{X^2+y^2}}{y}dy = \int_a^Y \frac{X^2+y^2}{y\sqrt{X^2+y^2}}dy$$

$$= X^2\int_a^Y \frac{dy}{y\sqrt{X^2+y^2}} + \int_a^Y \frac{y\,dy}{\sqrt{X^2+y^2}}$$

$$= \frac{X^2}{X}\left[\log_e\frac{\sqrt{X^2+y^2}-X}{y}\right]_a^Y + \sqrt{X^2+y^2}\Big]_a^Y$$

$$= X\left\{\log_e\frac{\sqrt{X^2+y^2}-X}{Y} - \log_e\frac{\sqrt{X^2+\alpha^2}-X}{\alpha}\right\} + \sqrt{X^2+Y^2} - \sqrt{X^2+\alpha^2}$$

$$B = \alpha\left\{\log_e\frac{\sqrt{\alpha^2+Y^2}-\alpha}{Y} - \log_e\frac{\sqrt{\alpha^2+\alpha^2}-\alpha}{\alpha}\right\} + \sqrt{\alpha^2+Y^2} - \sqrt{2\alpha^2}$$

$$A = X\left\{\log_e\frac{\alpha\left\{\sqrt{X^2+Y^2}-X\right\}}{Y\left\{\sqrt{X^2+\alpha^2}-X\right\}}\right\} + \sqrt{X^2+Y^2} - \sqrt{X^2+\alpha^2}$$

$$B = \alpha\left[\log_e\frac{\alpha\left\{\sqrt{\alpha^2+Y^2}-\alpha\right\}}{Y\left\{\sqrt{2\alpha^2}-\alpha\right\}}\right] + \sqrt{\alpha^2+Y^2} - \sqrt{2\alpha^2}$$

$$C = \int_a^Y \log_e\frac{\sqrt{X^2+y^2}-y}{X}dy$$

$$= \int y\log_e\frac{\sqrt{X^2+y^2}-y}{X}\Big]_a^Y + \int_a^Y \frac{y\,dy}{\sqrt{X^2+y^2}}$$

$$= Y\log_e\frac{\sqrt{X^2+Y^2}-Y}{X} - a\log_e\frac{\sqrt{X^2+a^2}-a}{X} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2}$$

$$D = Y\log_e\frac{\sqrt{\alpha^2+Y^2}-Y}{\alpha} - a\log_e\frac{\sqrt{2a^2}-a}{\alpha} + \sqrt{\alpha^2+Y^2} - \sqrt{2a^2}$$

$$\therefore \frac{I}{4} = X\left\{\log_e\frac{\alpha\left\{\sqrt{X^2+Y^2}-X\right\}}{Y\left\{\sqrt{X^2+\alpha^2}-X\right\}}\right\} + \sqrt{X^2+Y^2} - \sqrt{X^2+\alpha^2} - a\left\{\log_e\frac{\alpha\left\{\sqrt{\alpha^2+Y^2}-\alpha\right\}}{Y\left\{\sqrt{2\alpha^2}-\alpha\right\}}\right\} - \sqrt{2\alpha^2} - \sqrt{\alpha^2}$$

$$+ Y\log_e\frac{\sqrt{X^2+Y^2}-Y}{X} - a\log_e\frac{\sqrt{X^2+a^2}-a}{X} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2}$$

$$- Y\log_e\frac{\sqrt{\alpha^2+Y^2}-Y}{\alpha} - a\log_e\frac{\sqrt{2a^2}-a}{\alpha} + \sqrt{\alpha^2+Y^2} - \sqrt{2a^2}$$

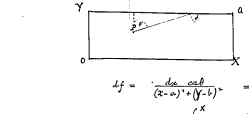
Let $\sqrt{X^2+Y^2} = \mathcal{D}$, $\sqrt{\alpha^2+Y^2} = \mathcal{Y}$, $\sqrt{\alpha^2+X^2} = \mathcal{X}$

$$\frac{I}{4} = X\left\{\log_e\frac{\alpha\left(\mathcal{D}-X\right)}{Y\left(\sqrt{X^2+\alpha^2}-X\right)}\right\} + \mathcal{D} - X - \alpha\left\{\log_e\frac{\alpha\left(\mathcal{Y}-\alpha\right)}{Y\alpha\left(\sqrt{2}-1\right)}\right\} - \mathcal{Y} - \alpha\sqrt{2}$$

$$+ Y\left\{\log_e\frac{\alpha\left(\mathcal{D}-Y\right)}{X\left(\mathcal{Y}-Y\right)}\right\} + \mathcal{D} - \mathcal{X} - \alpha\left\{\log_e\frac{\alpha\left(\mathcal{Y}-\alpha\right)}{X\alpha\left(\sqrt{2}-1\right)}\right\} - \mathcal{Y} - \alpha\sqrt{2}$$

$$= X\log_e\frac{\alpha\left(\mathcal{D}-X\right)}{Y\left(\mathcal{D}-X\right)} + Y\log_e\frac{\alpha\left(\mathcal{D}-Y\right)}{X\left(\mathcal{Y}-Y\right)} - \alpha\left\{\log_e\frac{\mathcal{Y}-\alpha}{Y\left(\sqrt{2}-1\right)} + \log_e\frac{\mathcal{D}-\alpha}{X\left(\sqrt{2}-1\right)}\right\} + 2\mathcal{D} - 2\mathcal{X} - 2\mathcal{Y} - 2\alpha\sqrt{2}$$

On the Inductance and field in a filamentary rectangle. (122)



Let oXaY be the rectangle
Consider as point P whose coordinates are a,b
The force at P due to an element dx in Ya is for unit current in Ya

$$df = \frac{dx\cdot ab}{(x-a)^2+(Y-b)^2} = \frac{dx\,(Y-b)}{\left\{(x-a)^2+(Y-b)^2\right\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (1)}$$

$$f = (Y-b)\int_0^X \frac{dx}{\left\{(x-a)^2+(Y-b)^2\right\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (2)}$$

The force at P due to an element dy in oY is similarly

$$f = a\int_0^Y \frac{dy}{\left\{a^2+(y-b)^2\right\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (3)}$$

From oX also

$$f = b\int_0^X \frac{dx}{\left\{(X-a)^2+b^2\right\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (4)}$$

and from aY

$$f = (X-a)\int_0^Y \frac{dy}{\left\{(X-a)^2+(y-b)^2\right\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (5)}$$

Let $(X-a) = \beta$ Let $(Y-b) = \gamma$

$$\therefore F = (Y-b)\int_0^X \frac{dx}{\left\{(x-a)^2+(Y-b)^2\right\}^{\frac{3}{2}}} + b\int_0^X \frac{dx}{\left\{(x-a)^2+b^2\right\}^{\frac{3}{2}}} + a\int_0^Y \frac{dy}{\left\{a^2+(y-b)^2\right\}^{\frac{3}{2}}} + (X-a)\int_0^Y \frac{dy}{\left\{(X-a)^2+(y-b)^2\right\}^{\frac{3}{2}}} \quad (6)$$

$$= \frac{1}{\gamma}\left\{\frac{\beta}{\sqrt{\beta^2+\gamma^2}}\right\} + \frac{a}{a^2}\left\{\frac{\gamma}{\sqrt{a^2+\gamma^2}}\right\} + \frac{1}{a}\left\{\frac{\gamma}{\sqrt{\gamma^2+a^2}}\right\} + \frac{b}{\sqrt{b^2+a^2}}\left\} + \frac{1}{b}\right\{\frac{\beta}{\sqrt{\beta^2+b^2}}\right\} + \frac{a}{\sqrt{a^2+b^2}}\left\} + \frac{1}{\beta}\right\{\frac{\gamma}{\sqrt{\beta^2+\gamma^2}}\right\} + \frac{b}{\sqrt{\beta^2+b^2}}\left\}\right\} \quad (7)$$

$$= \frac{1}{\gamma}\left\{\frac{\beta}{\sqrt{\beta^2+\gamma^2}}\right\} + \frac{1}{a}\left\{\frac{\gamma}{\sqrt{\gamma^2+a^2}}\right\} + \frac{1}{a}\left\{\frac{b}{\sqrt{a^2+b^2}}\right\} + \frac{1}{b}\left\{\frac{\beta}{\sqrt{\beta^2+b^2}}\right\} + \frac{a}{\sqrt{a^2+b^2}}\left\} + \frac{1}{\beta}\right\{\frac{\gamma}{\sqrt{\beta^2+\gamma^2}}\right\} + \frac{b}{\sqrt{\beta^2+b^2}}\left\}\right\} \quad (8)$$

$$= \frac{1}{\sqrt{\beta^2+\gamma^2}}\left\{\frac{\beta}{\gamma} + \frac{\gamma}{\beta}\right\} + \frac{1}{\sqrt{a^2+b^2}}\left\{\frac{b}{a} + \frac{a}{b}\right\} + \frac{1}{\sqrt{a^2+\gamma^2}}\left\{\frac{a\gamma}{\gamma} + \frac{\gamma}{a}\right\} + \frac{1}{\sqrt{\beta^2+b^2}}\left\{\frac{\beta}{b} + \frac{b}{\beta}\right\} \quad (9)$$

$$= \frac{\sqrt{\beta^2+\gamma^2}}{\beta\gamma} + \frac{\sqrt{a^2+b^2}}{ab} + \frac{\sqrt{a^2+\gamma^2}}{a\gamma} + \frac{\sqrt{\beta^2+b^2}}{\beta b} \quad \text{- - - - - - - - (9)}$$

$$= \frac{\sqrt{(X-a)^2+(Y-b)^2}}{(X-a)(Y-b)} + \frac{\sqrt{\{a^2+b^2\}}}{a.b} + \frac{\sqrt{\{a^2+(Y-b)^2\}}}{a(Y-b)} + \frac{\sqrt{\{(X-a)^2+b^2\}}}{(X-a)b} \quad (10)$$

And for any position of P whose coordinates may be x.y.

$$F = \frac{\sqrt{(X-x)^2+(Y-y)^2}}{(X-x)(Y-y)} + \frac{\sqrt{(x^2+y^2)}}{xy} + \frac{\sqrt{(x^2+(Y-y)^2}}{x(Y-y)} + \frac{\sqrt{(X-x)^2+y^2}}{(X-x)y} \quad (11)$$

$$\therefore I = \int_0^X\int_0^Y \frac{\sqrt{(X-x)^2+(Y-y)^2}}{(X-x)(Y-y)}dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{(x^2+y^2)}}{xy}dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{(x^2+(Y-y)^2}}{x(Y-y)}dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{(X-x)^2+y^2}}{(X-x)y}dx\,dy \quad (12)$$

Numerically, since each corner is taken in turn as origin of coordinates

$$I = 4\int_a^X\int_a^Y \frac{\sqrt{x^2+y^2}}{xy}dx\,dy.$$

The integration is taken from the lower limit a in each case a being put $= 0$

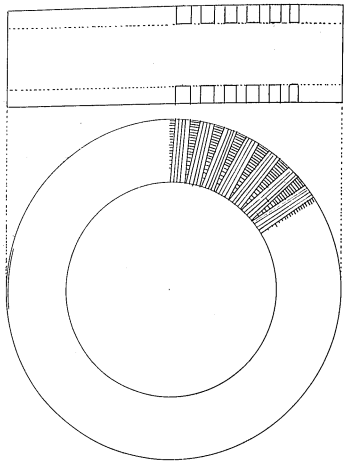
$$I = 4\int_a^Y \frac{dy}{y}\int_a^X \frac{\sqrt{x^2+y^2}}{x}dx$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\int \frac{x\,dx}{x\sqrt{x^2+y^2}}\right\}$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\int \frac{x\,dx}{\sqrt{y^2+x^2}} + \int \frac{y^2\,dx}{x\sqrt{y^2+x^2}}\right\}$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\left[\sqrt{y^2+x^2}\right]_a^X + \frac{y^2}{2y}\left[\log_e\frac{\sqrt{y^2+x^2}-y}{x}\right]_a^X\right\}$$

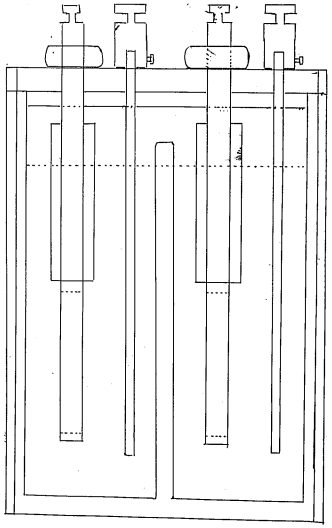
continued on opposite page



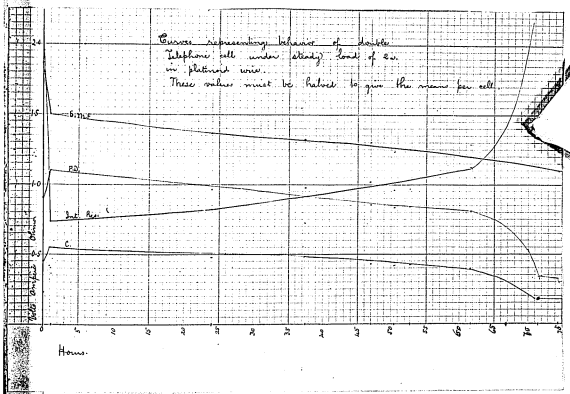
½ Armature Plan and Projection.

Determination of the best Dimensions for a 2½ H.P. Edison Small Motor to be wound for 500 250 and 125 volts.

Bipolar construction.
120 volts.
2000 Watts delivery.
80% commercial efficiency of armature at full load.
95% electrical " " " " "
2500 Watts intake at full load.
20.8 amperes intake " " .
6 volts drop in arm. " "
0.2885 ω resistance of armature not including platinoid (warm).
1500 rpm or 25 r.p.s. speed of armature.
$\phi w = 1.2 \times 10^{10}$ ∴ $\phi w = 4.8 \times 10^{8}$
For the 800 watt motor, $\phi = 300,000$. Consequently for 2000 watts,
$\phi = 3.0 \times 10^5 \times \left(\frac{2000}{800}\right)^{\frac{2}{3}} = 3.0 \times 10^5 \times 1.84 = 552,000$
$w = 872$ from this value of ϕ. and $w/42 = 20.8$ say 20.
$w = 840$ and revising with this value of w
$\phi = 5.7114 \times 10^5$ useful flux.
$\frac{\phi}{b} = 14,500$
$2b^{"} = 39.41$ sq. ins. $= 6.11$ sq. in. $= 3.055$ sq. in for $b^{"}$
$b = 1.75^{"}$. 4.45 cms
+ for the 800 watt motor is $4.5^{"}$. for this $4.5^{"}\left(\frac{2000}{800}\right)^{\frac{1}{3}} = 1.357 \times 4.5 = 6^{"}$ 15.24 cms
R " " " " " " " $7^{"}$ " " $7\left(\frac{2000}{800}\right)^{\frac{1}{3}} = 1.357 \times 7.0 = 9.5^{"}$ 24.13 cms
Internal circumference $= 18.85^{"}$ 47.88 cms $\div 42 = 0.4449^{"}$ $\phi 1.14$ cms.
External " $= 29.84^{"}$ 75.80 " $\div 0.711^{"}$ 1.805.
Area of external circle 70.882 sq. ins. 457 sq. cms
" " internal " 28.274 " " 181.5 " "
" " annulus 42.61 " " 275.5 " "
Mean length of one armature turn $8^{"} = 0.667'$
Length of wire on " $840 \times 0.667 = 560'$
Equivalent length for resistance $140'$
Resistance per foot $0.2885/140 = 0.002061\,\omega$ $= \#12$ B&S. $0.0808^{"}$
Covered diameter $0.081 + 0.015 = 0.096^{"}$
Width of groove $4 \times 0.096 + 0.020 = 0.404^{"}$
" " wall at 4ϕ $0.4449 - 0.404 = 0.045^{"}$, at periphery $0.711 - 0.404 = 0.307$
Depth " groove $5 \times 0.096 + 0.028 = 0.500^{"}$. 1.27 cms
Width " armature $1.75^{"} + 0.5^{"} + 0.5^{"} = 2.75^{"} = 6.99$ cms
Area of each groove on surface $0.404^{"} \times 1.75 = 0.707$ sq. ins. 4.56 sq. cms
Total area of annulus on one side occupied by grooves $= 29.7$ sq. ins. 191.6 " "
" " " " " " " " teeth $= 12.9$ " " 83.2 " "
Area on the surface of each tooth 0.307 " 1.98 " "
Teeth active on one side $42 - 12 = 30$.
" under each pole 30.
Plan area $30 \times 1.98 = 59.4$ sq. cms.
Induction density (mean) in teeth $571,000 \div 59.4 = 9620$.
Peripheral velocity of armature $75.8 \times 25 = 1895$ cms per sec. $2.49 \times 1500 = 3730$ fpm
Volume of armature core $275.5 \times 7 = 1928.5$ c.c.
Reduction for grooves $191.6 \times 1.27 \times 2 = 487$ c.c.
Reduced volume of core 1441.5 c.c.
" mass of core @ sp.g. of $7.5 = 10,811$ gms. $= 23.8$ lbs.
Flux estimated through core centre $1,143,000$ $\frac{\phi}{b} = 13,000$ area $= 88$ sq. cms
Diameter $10.6^{cms} = 4.25^{"}$



Full size section of cell. Breadth of cell is equal in both directions, so that the plan of the cell is square.
500 c.c. of solution 1·25 sp.g. in each compartment
Weight of Cu O. plates about 107 gm. Weight of copper frame 90 gm
" Zn " " 92 "


Curves representing behaviour of double
Telephone cell under steady load of 2 a.
in platinum wire.
These values must be halved to give the mean for cell.
Hours.

Test of some switches for carrying capacity

Seven switches were received from the Engineering Department for test.

No 1. bipolar double break switch marked for 120 lamps
2 " " " " " 60 "
3 " " " " " 30 "
4 " " " " " 15 "
5 " " " " " 10 "
6 " single " " " — "
7 " " " 3-way " — "

As regards the sparking at the brushes, no 1 will break a simple non-inductive lamp circuit of 110 V. no. 2 nearly as much, while even the 10 light switch will break 40 A safely. The limiting carrying capacity is therefore determined by the heat generated in the apparatus. The limit of temperature elevation selected was 15° C. above normal, in this instance from 20° to 35° generally.

Under these conditions #1 carried 75 amp. or @ 0·1435 172 lamps
" #2 " 38 " 87 "
" #3 " 24·4 " 55 "
" #4 " 18 " 41 "
" #5 " 15 " 34·5 "
" #6 " 10 " 23 "

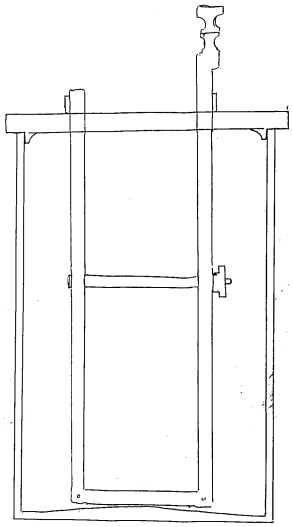
Recommended to the Engineer-in-Chief that the
#1 or present 120 lt switch be used for 160 lt
#2 " " 60 " " " 80 "
#3 " " 30 " " " 40 "
#4 " " 15 " " " 30 "
#5 " " 10 " " " 20 "
#6 " " 3 " " " 10 - or less

Test of a double telephone Edison-Lalande cell in a porcelain jar

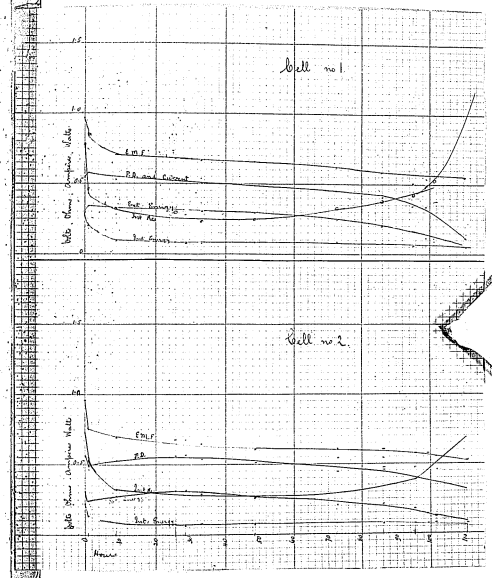
	Date	Time	Hrs from start	EMF	PD	Drop	Int. res.	Current	C^2	Int. H.	Int. Energy watts	Elec. energy watts	Mean θ	Ex Mn.	Amp Mn.
	3rd	12·00	0	1·900	0·866	1·034	1Ω	1·034							
	4th	9·30	0	1·860	0·900	0·960	2Ω	0·480	1·228	2·13	1·149	0·456			
	"	10·45	1·25	1·870	1·100	0·40	"	0·550	0·3025	0·73	0·22	1·60	0·515	1·25	0·644
	"	9·20	24	1·362	0·966	0·396	"	0·483	0·2333	0·82	0·19	0·467	0·517	22·75	11·76
	"	23·00	37·5	1·320	0·972	0·348	"	0·486	0·2362	0·72	0·17	0·1672	0·485	13·5	6·55
	6th	8·30	47	1·292	0·854	0·444	"	0·427	0·1823	1·01	0·19	0·365	0·456	9·5	4·33
	"	12·0	50·5	1·234	0·826	0·409	"	0·417	0·1739	0·96	0·17	0·346	0·422	3·5	1·48
	"	14·15	52·75	1·250	0·842	0·408	"	0·421	0·1772	0·97	0·17	0·354	0·419	2·25	0·943
	"	23·15	61·75	1·258	0·806	0·452	"	0·403	0·1624	1·12	0·18	0·325	0·412	9·0	3·70
16	7th	9·0	71·5	1·124	0·334	0·790	"	0·167	0·0279	4·73	0·13	0·058	0·285	9·75	2·78
11		12·0	74·5	1·120	0·322	0·798	"	0·161	0·0259	4·96	0·13	0·052	0·162	3·0	0·49
12		Weight of zinc plate				before	last	#1	82·67		#2	80·65		Tot	32·67
13						after	-	#1	43·37		#2	40·93			
									39·30			39·72			
									Mean	39·51			Calculated loss		39·6 gm.

both directions.

6 gm.



Section of cell full size



Test of Edison-Lalande Telephone cells. 3rd to 6th Apr.

Two of Rhess cells were set up with $\frac{1}{10}$ NaHO solution of density 1.26.
The weight of the zinc plate in #1 was 85.71 gms. Copper oxide 103.1 gms
" " " " " #2 " 83.7 " " 93.5 "
The cells were set to work independently upon 1 ω.

No of obs	Date	Time from start	EMF	PD	Drop in cells	Batt R.	Current	C^2	Batt. energy	R of cell	Batt. energy	Mean Amp.	Amp hrs.	Amp Hrs
1	2nd April 9.0	0	0.966	0.584	0.432	1ω	0.5044	0.296	0.296	0.776	0.229			
2		9.40	0.67	0.940	0.576	0.264		0.576	0.332	0.332	0.458	0.152	0.560	0.67	0.37
		17.50	8.83	0.704	0.528	0.176		0.528	0.279	0.279	0.333	0.093	0.552	8.13	4.49
	3rd	10.50	25.5	0.678	0.524	0.154		0.524	0.275	0.275	0.294	0.081	0.526	17.0	8.94
5		13.20	28.3	0.672	0.548	0.124		0.548	0.300	0.200	0.226	0.068	0.524	2.5	1.32
6		17.50	32.8	0.666	0.534	0.132		0.534	0.285	0.285	0.247	0.071	0.541	4.5	2.444
7	4th	9.30	48.5	0.654	0.492	0.162		0.4792	0.242	0.242	0.329	0.080	0.513	15.67	8.04
8	5th	9.30	72.5	0.614	0.448	0.166		0.4048	0.201	0.201	0.375	0.075	0.470	24.0	11.28
9		23.0	86.0	0.588	0.488	0.172		0.4408	0.166	0.166	0.422	0.070	0.429	13.5	5.798
10	6th	9.30	95.5	0.588	0.340	0.168		0.340	0.116	0.116	0.494	0.057	0.374	9.5	3.55
11		12.0	99	0.536	0.340	0.196		0.340	0.116	0.116	0.577	0.067	0.340	2.5	1.19
12		14.15	101.3	0.562	0.370	0.192		0.370	0.137	0.137	0.524	0.072	0.365	2.25	0.80
13		23.15	110.3	0.550	0.110	0.4440		0.110	0.0121	0.0121	4.00	0.048	0.240	9.1	2.16
														119.23	50.96

Cell No 2.

No of obs	Date	Hours from start	E.M.F.	P.D.	Drop in cells	Batt R.	Current	C^2	Batt. Energy	R of cell	Batt. energy	Mean Amp.	Amp hrs.	Amp Hrs
1	2nd	9.0	0.96	0.556	0.4014	1ω	0.536	0.309	0.309	0.727	0.225			
2		40	0.67	0.760	0.496	0.264		0.496	0.246	0.246	0.532	0.131	0.516	0.67	0.35
3		17.50	9.0	0.692	0.520	0.168		0.5244	0.275	0.275	0.321	0.088	0.508	8.13	4.15
4	3rd	10.50	25.5	0.694	0.558	0.136		0.558	0.311	0.311	0.243	0.076	0.541	17.0	9.20
5		13.20	28.5	0.678	0.562	0.116		0.562	0.316	0.316	0.206	0.065	0.560	2.5	1.40
6		17.50	33.	0.674	0.536	0.138		0.536	0.287	0.287	0.257	0.074	0.549	4.5	2.47
7	4th	9.30	48.5	0.642	0.508	0.134		0.508	0.258	0.258	0.264	0.068	0.522	15.67	8.18
8	5th	9.30	72.5	0.612	0.448	0.164		0.448	0.201	0.201	0.366	0.074	0.478	24.0	11.47
9		23.00	86.	0.604	0.456	0.148		0.456	0.208	0.208	0.324	0.068	0.462	13.5	6.10
10	6th	9.30	95.5	0.570	0.416	0.154		0.416	0.173	0.173	0.370	0.064	0.436	9.5	4.14
11		12.0	99	0.570	0.370	0.20		0.370	0.137	0.137	0.540	0.074	0.393	2.5	1.38
12		14.15	101.3	0.550	0.358	0.192		0.358	0.128	0.128	0.536	0.069	0.3614	2.25	0.82
13		23.15	110.3	0.526	0.310	0.216		0.310	0.0961	0.0961	0.697	0.069	0.334	9.0	3.01
															52.67

Density of solution after test 1.35.
Weight of zincs No 1. 22.82 gms. No 2 · 18.02 gms (No 2 broke off in center between obs. nos. 10 and 11.
Cu oxide plate No 2 90 gms No 1. 102.
· 50.36 × 1.212 = 61.05 gms. Calculated consumption in #1 cells actual loss 62.89 error 1.84
52.67 × 1.212 = 63.85 " " " #2 " " 65.68 1.83
There seemed to be about 10% by estimation of Cu2 left in the negative plates.
The cells hold about 600 c.c. of solution.

Nucleus of a dynamical theory of electricity 7th April 91.

The jostling of molar dissimilar molecules, usually occurring at the bounding surfaces of bodies in contact, either in virtue of the dissimilarity of structure, or more probably in virtue of a mere dissimilarity of dynamical relationship sets up a vortical motion in themselves and in the ether between them. Motion in order to be but energy must be rectilinear. Vortical motion is electrical energy. The mere difference in molar due to difference of temperature will on clashing produce a disturbance whose resultant will be vortical motion, hence thermo-electricity. Vortical motion once set up is likely to continue indefinitely. In uniform activity it produces no phenomena beyond dynamical stresses in the media it traverses.

The establishment of vortical motion in any medium requires an expenditure of energy. The reactive forces or inertia stresses brought into activity and overcome by the vortex forming force is magnetic force, and the magnetic force is thus always proportional to the vortical acceleration. In a non-conducting medium the vortices are established once for all by electric force, that is by communication of the vortex motion of superficial molecules to the intervening medium. The production of the vortices in the medium sets up a momentary reaction or magnetic field but that is all. If however the medium be conducting, the vortices are absorbed in its substance the molecules receiving the motion in the form of oscillations. Their nature and structure dynamically permits of this.

The vortex forming force continues in activity and the reaction or time rate of vortical development sustains in the medium a permanent magnetic field in lines radiating from the conductor and the reactionary field sets up movement also vortical but in the opposite sense.

These reactionary forces that are generated by wave impulses themselves constitute an antithetical vortex motion. The rate of development of the reactionary vortices, for precisely converse reasons dynamically react upon the conductor and generate a reverse current in it. Or reaching other conductors their rate of change sets up in them reactionary vortices which are of the first kind (current) in them, thus explaining electrostatic induction.

Electrostatic forces are purely vortical motion forces

Electromagnetic forces are reactionary vortical forces

If this theory is true, the rapid rotation of a non-conducting liquid in a non conducting (glass say) tube might be expected to develop some feeble magnetic action in its neighborhood, during starting and stopping, but not during steady running.

Particulars of Edison 100 Kilo Watt Multipolar Dynamo.

150 volts, 666 amperes, 172 revolutions.

ARMATURE.

Outside diameter,	66"
Inside diameter,	57"
Width,	12-3/8"

Body to contain 2200 lbs. of #21 B.W.G. oxidized iron wire.

Armature winding in square bars of 56000 square mils cross section, 944 turns all around, or 118 turns per pole.

Total resistance of armature (eight sections in multiple arc) 0.0059 ohms at 0° C.; 0.00755 at 70° C.

Drop in armature at full load, 5 volts. Watts lost in armature, 3390.

MAGNETS.

Diameter of Cores,	12"
Length,	16-1/2"
Bore of Field,	67-3/16"

Field winding, 335 pounds of #12 B.W.G. per core, 2680 lbs. total. Two cores connected in series, four sets on multiple arc.

Resistance per core, cold,	7.6 ohms
Total resistance of shunt, cold,	3.8 ohms.

DATA OF CALCULATION.

Total useful flux,	22,900,000 lines,
" " through armature,	2,860,000 lines,
Intensity in armature,	8,000 lines

Flux through cores (leakage coefficient calculated 1.55)

	4,433,000 lines
Intensity in cores,	6,200 lines

Results of preliminary tests on January 31st, 1891.

Speed, 176 revolutions

Maximum voltage obtained at no load, field resistance all out, 165 volts, with 39 amperes in the shunt as exciting current.

The machine was placed upon an unsteady foundation and consequently could not be loaded up to full capacity. Load was part-

ly on the shop light circuit, and partly on an iron wire resistance. The following readings show the increase of E.M.F. with decreasing load:-

Current in Main Circuit Amperes	E.M.F. on Brushes Volts	Current in Field Amperes
270	128	30.8
235	130	31.2
205	135	32.4
185	137	33
160	140	33.6
120	142	34
95	142	34
75	143	34.4
58	146	35
30	150	36

During the variation of load no movement of the brushes was required and no sign of sparking was noticed on the brushes.

With the load of 128 volts and 270 amperes, the machine was run for one hour and forty minutes: the increase of temperature on the armature after this time was 22° C.

For a short time, a load of 340 amperes was put on the machine, but it had to be taken off on account of the armature striking against the field. Even with this load no movement of the brushes was necessary.

NOTE. The armature body No 1, which was under test, contains but 1450 lbs. of oxidized iron wire of a small gauge (#24 B.W.G.) There is another arma finished, which contains 2212 lbs. of iron wire of a larger gauge (#21 B.W.G.) and which will no doubt give far better results.

Schenectady Works,
March 14th, 1891

$0.00983 \times \frac{10630 + 2672}{2672} = \frac{0.00983 \times 13302}{2672} = 0.048893$?

$0.10 \times 1.000002 \cdot \frac{0.100002 \times 2672}{2672} = 0.024912$ reliable.

$0.024912 - x : x :: 2684x : 2672$

$2684x = -2672x + 2672 \times 0.024912$

$5356x = 2672 \times 0.024912$

$x = 0.012450$ lower half

$1-x = 0.012462$ upper half.

12th. Apr. 81

C. Vanderson Esq.

Engineer-in-Chief

Edison General Electric Co.

New York.

Dear Sir,

The following are the results of our tests on the sample of
silicon-bronze trolley wire from Moonton N. J., referred
to in your letter of the 9th. inst.

Gauge B & S No. 0 Mean diameter 0.235"

Specific gravity 8.85

Weight per foot 0.1716 lbs. per mile 906 lbs.

Conductivity 41.7 % of Matthiessen's standard hard drawn
copper at temperature of test (19° C.)

Resistance per foot at 20° C. 0.00048 ohm, per mile 2.374.

Tensile strength 8200 lbs. weight(no appreciable extension
by any stress under 8000 lbs.) for 21,100 lbs. per s...

Flexibility 96.5 bends to fracture in twelve inches.

Full particulars of tests can be supplied on demand.

Yours faithfully,

Consulting Electrician.

Tests of a sample of Trolley Wire Silicon-Bronze manufactured at Boonton N. J. 11th Apr. 91.

[...]t 100 feet of this wire was received. on the 10th apr. see letter of 9th from N.Y.

[...]uage measurements.

[...] length of about 75 feet was stretched along the floor, and the [...]uage was taken at every 3 feet as follows:— Brown & Sharpe Micrometer

2	0.2399
3	0.2397
4	0.2395
5	0.2388
6	0.2397
7	0.2401
8	0.2394
9	0.2393
10	0.2390
11	0.2394
12	0.2395
13	0.2391
14	0.2386
15	0.2390
16	0.2392
17	0.2394
18	0.2390
19	0.2393
20	0.2397
21	0.2398
22	0.2396
23	0.2394
24	0.2393
	93
Mean	0.23939

Mean diameter 0.23939" = 0.6081 cm.

" area 0.04502 □" in = 0.2905 sq. cm.

Weight. a length of 273.0 cms weighed 1 lb. 453.6
8 oz 226.8
255 grs. 16.5 696.9 gms.

" " per cm = 2.553 gms.

" " c.c. = 8.786 "

" " foot = 77.8 " = 0.1716 lb.

" " mile = 410,800 " = 905.8 lbs.

Sp: g: by direct measurement. Weight of a small sample in air 11.945
" water 10.607
1.338

Sp. g. 8.926.

Breaking strain by Spring dynamometer:—

Two samples ~~soldered soldered~~ broke at 3200 lbs. Stretching commenced visibly at 3000 lbs. Both fair breaks in center of specimen.

3200 lbs = 1451.5 kgms = 71,080 lbs per □" in = 4997 kgms per sq. cm.

Ductility. Twisted between lathe centers. one end held, other free in line of axis. Sample #1 12" broke at 17 complete twists
#2 12" " " 16 " "
#3 12" " " 13 " "

The last sample #3 broke at the clamp and may therefore not have been a fair test.

Conductivity. H. & B Diff: Galv. 10 ω in cct: for balance with L.H. coil. Res. of each coil 2672 ω.

Five lengths of the trolley wire were measured, and pressure wires attached at the points marked.

No 1.	326.45
" 2	733.95
" 3	1049.28
" 4	1571.25
" 5	2060.55.

Preliminary balances. Standard 0.01 ω @ 22°C. : Platinoid grid :: 2672 : 2672+10[...]
Standard 0.1 ω @ 22°C. : grid :: 2672 + 2770 : 2672

Upper half of grid : Lower half :: 2672 + 12 : 2672

$$= (1.0737)\,1634 = 1754$$

$$= (2.2227+1)\,1593.5 = 1711$$

$$= (1.0194)\,1634 = 1659.5$$

$$= (1.0737)\,1634 = 1754$$

$$= (1.00388+1)\,1634 = 1691$$

$$= (1.00388\times 5+1) = (1.00388\times 5+1)$$

Ref. No.	Item
1	2nd
2	2nd

DATA FOR THE EDISON EXPERIMENTAL LIGHTNING PROTECTOR.

Materials and Labor Required for One Protector.

Two such strips are rolled up together with [illegible] long and 3" wide paraffined paper about 2½" long and 3" wide with two strips of

Each paper strip is composed [illegible] and 0.01" thick, sheets of thin tissue paper, [illegible] being itself made up of four soaked in molten [illegible] as silver tissue paper.

One leadfoil strip is [illegible] rolled up with a kerite wire bound within the lead, 0.0[illegible]" covered to 0.20", the other leadfoil strip is rolled upon a loaded wire 0.07" diameter. These wires or electrodes are about 18" long, and each communicates with one portion of the condenser. The total area of active surface is 1.8 sq. feet. The exact length of strips used will vary with the skill of the operator who rolls them up.

The roll is made up on a hot plate, and is then inserted in a plain zinc tube 6" long, 0.[illegible]" int. 0.[illegible]" external diameter. The two electrodes project out from each end.

The ends of the tube are then sealed with a composition of asphalt, linseed oil (boiled), and a special powder known as Phonograph powder as made by the [illegible] Co. of Newarkjersey. The resulting compound (40% by weight asphalt, 30% of boiled linseed oil, and 30% of powder) makes a high temperature melting point that will [illegible] at normal temperature without softening. Care has [illegible] be taken in pouring it in not to melt the lead wire.

A strip of zinc is soldered on to the tube before the condenser is inserted to serve as a holder by which it may be nailed up to a pole crossarm.

The tubes then receive a coating of air-dry japan.

They are then tested at a pressure of 1250 volts. They give a spark on discharge after receiving this pressure and are capable of giving a shock if left insulated for more than an hour afterwards.

The mean capacity of [illegible] electrodes is 0.01 microfarad with a mean [illegible]

The approximate cost of [illegible] used in the [illegible]

[illegible]	3.25 c.
[illegible]	1.5
[illegible]	0.6
[illegible]	1.2
zinc tube [illegible]	3.4
asphalt composition	1.05
Total	8.75

The best place for one of these arrestors is on the cross-arm of a pole next to the wire it protects and close to the [illegible]. The [illegible] is connected with preferably solder to the [illegible] and the lead wire which should be on the inner end is connected direct to ground. On down the pole, [illegible] a ground plate [illegible] or to a water pipe. The [illegible] connection should in all cases be as direct as possible, the function be more the ground wire will [illegible] wire should be covered with tape and made water-tight.

A common ground wire may serve several arrestors on the same pole.

	Length of Rollywire used	Standard	Res. of Std.	Resistance for balance	L	Ratio	Res. of wire	Ri of wire per cm.	Resistivity	Conductivity $\times \frac{1}{1063}$	Temp. of wire
1	2060.55	grid	0.014913	1730Ω	grid	$\frac{4463}{2672}$	0.032982	1.6478×10^{-5}	4.205×10^{-6}	0.4069	14°C
2	2060.55	Loom half	0.02245	2571Ω	wire	$\frac{3263}{2672}$	0.024770	1.443	4.192	0.4080	"
3	25	"	"	206Ω	grid	$\frac{2878}{2672}$	0.332766	1.4475	4.205	0.4069	"
4	28	"	"	1636Ω	"	$\frac{4308}{2672}$	0.315495	1.448	4.206	0.4068	"
5	3.95	"	"	3478Ω	"	$\frac{6150}{2672}$	0.0106444	1.4503	4.213	0.4062	"
6	3.95	0.01Ω	0.00983	225Ω	wire	$\frac{2697}{2672}$	0.010660	1.4528	4.220	0.4055	"
7	2.45	"	"	2860Ω	0.01Ω	$\frac{2723}{2672}$	0.007149	1.456	4.227	0.4047	"

check, compared the wire with a copper rod already used in low case see p. 86. Length of rod between electrodes 273.8 area of section 0.3267. Equivalent length of 0.2905 = 2423.5 cms. Balanced against this at 1114.0 cms. of Rollyj wire = relative conductivity 0.468

Resistivity at 14°C. 4.205×10^{-6} Conductivity 0.4069 of Matthiessen's Std at temp 14°
" " 0.4147 " " hard-drawn " "

Resistance per cm @ 14°C 1.4475×10^{-5} Ω = @ 24°C. 1.476×10^{-5}
" - foot @ 14°C 4.412×10^{-4} Ω = " 4.497×10^{-4}
" - mile " 2.329 " = " 2.374 Ω.

On Condenser lightning arrestors.

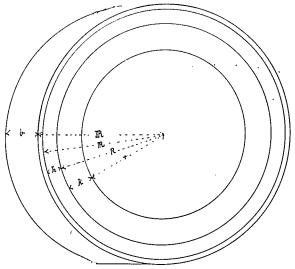
The condensers are made up of two strips of Tinfoil 6" wide and 7' long) 0.0015" thick (0.0038 cms.) separated by three sheets of Paraffined paper of total thickness 0.01" or 0.025. The surface of condenser is thus 2 (6"×7") = 1.45 sq. ft. = sq. cms. The two sheets are rolled up with a lead wire 0.074" = #15 B&S. and Kerite wire 0.067" covered to 0.20". respectively. The roll is inserted in a zinc tube 9" (22.9) long and 0.85" diam. ext: 0.825" int: diameter. Its own length is about 7.5". The two ends of the zinc tube are plugged with a composition of asphalt 0.8 Paraffin #1 and 0.1 and boiled linseed oil 0.1. This makes a high melting point asphalt. The capacity of the condenser is about 0.01 μF made up with only two thicknesses of paper (silver leaves paper) the condenser break down under 1200 volts. When made up with 4 paper they generally stand 2400. A spark or series of sparks if passed through the condenser from a Holtz machine did not cause the condenser to break down under a subsequent application of 1200 volts.

The approximate cost of material in the condenser is :-

1.5	feet of Kerite wire @ 1.5 per foot	2.25
1.5	" Lead fuse wire @ 0.75 per lb. = 50 lb of 1 lb. in weight	1.50
3.0	feet of 1 inch Lead foil @ 16 ¢ per lb.	0.5
	6 X 2.0 = 12' of paper @ $1.20 per ream	1.2
	Zinc tube 9" @ 18 ¢ per lb. 1/2 lb of 1 lb	3.3
	Asphalt Composition	1.0 ?
	Total material.	9.75

Asphalt @ 4¢ per lb.
Linseed oil @ 60¢ per gal.

Total 10¢ as complete



Let r = internal radius (cms) of core proper
R = external " " " "
R = internal " " winding space
R = external " " armature
b = breadth of core (cms)
h = $(R-R)$ or winding depth
k = $(R-r)$ or core depth
p = number of poles.
g = width of polar gap measured along periphery (cms) = αR
α = coefficient of polar gap.
t = Ratio of both surfaces to periphery of armatures at radius R
w = number of wires all round
d = diameter of wire cms
D = covered diameter " "
$\gamma = \frac{2}{\pi}$
ρ = resistivity of wire A.E.M.U. at working temp.
ϖ = length of one turn round armature cms
σ = resistance of armature between brushes A.E.M.U
B = Mean induction density in both cgs. lines per sq.cms
$\mathcal{B}$ = " " " " armature core " " "
ϕ = polar useful flux
ψ = armature " " $= \phi/2$
E = EMF generated by armature A.E.M.U.
n = revs. per sec. of armature.
$x = \frac{R-r}{b} = \frac{k}{b}$
j = coefficient of increase in σ due to winding. runs and above $2(K+k+b)$

Revised Formulæ for the Determination of Multipolar Motors

$$E = \phi n w \tag{1}$$

$$\phi = 2\mathcal{B} b k \tag{2}$$

$$\sigma = \frac{w \varpi \rho}{\beta^2 d^2} \tag{3}$$

$$\varpi = 2(b + K + 2h) \tag{4}$$

$$w \beta^2 d^2 = 2\pi R (1-t) h \tag{5}$$

$$2\pi n R = V \tag{6}$$

$$b R = s H \tag{7}$$

$$\text{where } H = (F + c\sigma) \tag{8}$$

In the problem E, n & p are given
This allows H, and σ to be determined.
V is also to be decided upon, while s is to be calculated from machines of similar type

(a) R is first calculated from (6)

(b) b is then obtained " (7)

(c) $w = \sqrt{\frac{\sigma \beta^2 \pi R h (1-t)}{\rho \varpi^2 (b + K + 2h)}}$ from (3) (4) & (5)

(d) $K = \frac{E}{2\mathcal{B} b n w}$ from (1) & (2)

In (c) R is taken equal to R. t is given a trial value, which must be subsequently examined for mechanical conditions and by the formula

$$t = \frac{\phi}{\mathcal{B} b R \left(\frac{2\pi}{p} - \alpha\right)}$$

γ is also estimated and k is given a (preliminary) value which may need revision after (d) has been worked out. If the values for R, b, w, and k as thus determined are consistent, the magnetic circuit has next to be examined

Formulae for the Determination of Multipolar Gramme Ring Motors

$$E = \phi n w \quad (1)$$

$$\phi = 2\mathfrak{B} b k \quad (2)$$

$$= 2\mathfrak{B} b^2 x \quad (3)$$

Total polar surface $= b\left(2\pi R - \frac{bq}{p}\right) = b\frac{\mathfrak{R}}{p}(2\pi - \alpha p)$

$$= b\mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right) \quad \ldots$$

Useful " " $= bt\mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right) \quad - - - - - - - - - \quad (4)$

$$\Phi = btB\mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right) \quad - - - - - - - - \quad (5)$$

$$\alpha = \frac{w\varpi\rho}{p^2 d^2}$$

$$\varpi = 2(b + k) + 2h)$$

$$w y^2 d^2 = 2\pi R (1-t) h$$

$$\therefore \Phi = \frac{2w^2(b+k)+2h)\rho y^2}{2p^2\pi R(1-t)h} \quad \ldots \quad (6)$$

From (1) & (3) $E = 2\mathfrak{B} b^2 x n w \quad - - - - - - - \quad (7)$

(3) & (5) $b = \frac{B t \mathfrak{R}}{2\mathfrak{B} x}\left(\frac{2\pi}{p} - \alpha\right) \quad - - - - - - - \quad (8)$

$$\therefore E = \frac{1}{2} n w \frac{B^2 t^2 \mathfrak{R}^2 \left(\frac{2\pi}{p} - \alpha\right)^2}{2\mathfrak{B} x} \quad \ldots \quad (9)$$

$$w = \sqrt{\left\{\frac{\varpi p^2 \pi R (1-t) h}{\rho y^2 \{b(1+x) + 2h\}}\right\}} \quad \ldots \quad (10)$$

$$E = \frac{n B^2 t^2 \mathfrak{R}^2 \left(\frac{2\pi}{p} - \alpha\right)^2}{2\mathfrak{B} x} \sqrt{\left\{\frac{\varpi p^2 \pi \mathfrak{R} (1-t) h}{\rho y^2 \{b(1+x)+2h\}}\right\}} \quad \ldots \quad (11)$$

$$\mathfrak{R}^{\frac{5}{2}} = \frac{2\mathfrak{B} x E}{n B^2 t^2 \left(\frac{2\pi}{p} - \alpha\right)^2} \sqrt{\left\{\frac{\rho y^2 \{k(1+\frac{t}{2}) + 2h\}}{\varpi p^2 \pi (1-t) h}\right\}} \quad \ldots \quad (12)$$

We are supposed to know $\mathfrak{B}$, E, B p α n ρ ϖ

Further $w = \sqrt{\frac{\varpi p^2 \pi R (1-t) h}{\rho y^2 \left[\left(\frac{B t \mathfrak{R}}{2\mathfrak{B} x}\right)\left(\frac{2\pi}{p} - \alpha\right)\{1+x\} + 2h\right]}}$

$$= \sqrt{\frac{\varpi p^2 \pi (1-t) h \, 2\mathfrak{B} x}{\rho y^2 B t \left(\frac{2\pi}{p} - \alpha\right)(1+x+j)}} \quad \ldots \quad (13)$$

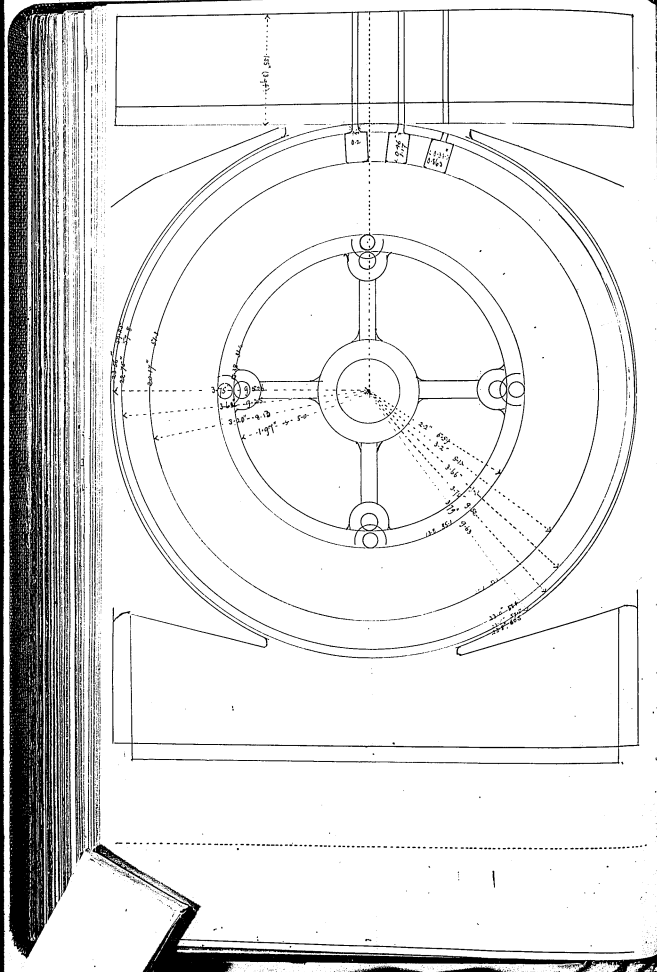
and $\mathfrak{R}^2 = \frac{2\mathfrak{B} x E}{n B^2 t^2 \left(\frac{2\pi}{p} - \alpha\right)^2} \sqrt{\frac{\rho y^2 B t \left(\frac{2\pi}{p} - \alpha\right)(1+x+j)}{2\varpi p^2 \pi (1-t) h \, 2\mathfrak{B} x}} \quad \ldots \quad (14)$

Here x & y are given trial values
while t, h, and j are estimated.

This determines R.

b is then to be found from (8)

w from (13) or (10)



Specifications for a 1 HP 120 volt motor.

1800 r.p.m. = 30 r.p.s.

Delivering 800 Watts at 0.90 armature electrical efficiency and 120 v. at motor terminals.

At 0.70 commercial efficiency the current energy in the motor is $\frac{800}{0.7}$ = 1140 watts ÷ 120 = 9.5 amperes. 8.0 × 120 = 420 volts $\frac{120}{9.5}$ = 12.6Ω hot. = 11Ω for the armature without platinoid wire.

The cross section of the armature core is 10 sq. cms. of which 09 is available for wire = 9 sq. cms. ~~and 0.8×2.3 = 1 sq. cm reduction for bolt space leaves 8 sq cms~~ × 17,000 = 153,000 lines say 150,000 or a total flux of 200,000. the number of turns must be 1320 of which the nearest even multiple of 36 is 37.

The mean turn will have a length of 0.6' and 1332 turns = 799.2' for 1.1Ω = $\frac{209}{1.1}$ = #32' per ohm. @ 100° C = 0.04Ω' = #18 B.W.G. covers this wire with be 0.059", and 5 wide = 0.295" + 0.025" = 0.320" 7 wire high = 0.413" + 0.025" = 0.438".

36 groove, 36 commutator blocks.

Depth of groove 0.44", width 0.320".

Width of wall 0.312" above, 0.24" below. (0.792, + 0.610)

Polar length = T_g ½° of $\frac{59.85}{2}$ = 23.3 × 3.0 = 70 sq. cms polar area.

Polar angle $\frac{35}{9}$ × 360 = 140°. Gap angle 140°.

Sectional projection, mica 0.010", wire 0.010". clearance 0.020" - 0.040" = 0.1 cm. Polar reluctance $\frac{0.1}{70}$ = 0.0014, say 0.015".

Total gap reluctance 0.0030

Breadth of armature 1.25" (3.16)

Total flux allowed for in field magnet 600,000 at density of 15,000 = 40 sq. cms. = 7.12 cms. diam = 2.81".

When the machine was laid out for a working drawing, it was found that there was not sufficient room in the interior of the armature for coiling the wire. On this account the int: diameter was increased to 4.40". The cross section of the armature being 1.55 sq. in., the width of the armature core will be 1.55".

The wire used in winding a preliminary model is 0.064" covers to 0.061", and five wide = 0.305" + 0.032" = 0.335" seven high = 0.427 + 0.030" = 0.457

Each wall will now be $\frac{55.4}{50}$ - 0.863 = 1.622 - 0.863 = 0.759 (0.8") above and $\frac{51.1}{50}$ - 0.863 = 1.1420 - 0.863 = 0.557 (0.22") below.

14 walls carry the total flux = 14 × 0.557 × 3.94 = 30.7 sq. cms. an average density of $\frac{300,000}{30.7} \times \frac{1}{0.8}$ = $\frac{300,000}{24.56}$ = 12,209.

Length of wire in 35 turns 19 feet. 0.54Ω per turn.

Surface of armature is $2\pi\,(9.63^2 - 4^2) + 8\pi(9.6 + 4)$ = $2\pi\,(92.7 - 16 + 54.4)$ $2\pi\,(131)$ = 823 sq. cms.

Heat developed in armature will be 100 Watts for forecasts + 9.5²×1.1 = 90.2 × 1.1 = 99.2 for armature resistance say 200 Watts in all.

The peripheral speed of the motor will be 30 × 2π × 9.6 × 0.9 = 1628 lines

The mean speed $\frac{\text{lines}}{\text{sec.}}$ of armature = 60 × 4 × 1628 + 592.4 × 1153 + 100 × 670 = 396,700 + 67,000 + 67,800 = 1,130,000 c.c. per sec: for 200 Watts = 5650 c.c. per sec: for Watt.

Test of Alternator at Schenectady 13th April

The new armature in this motor has the same dimensions as the previous one, and is wound with copper wire in the same manner but its body is made up of square oxydised iron wire 0·05" × 0·05".

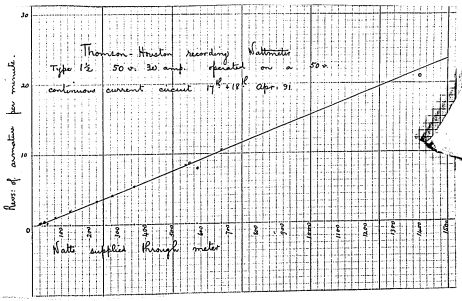
Current was turned on the field at 9.44a am, the machine making 1200 r.p.m. Readings taken with a Cardew voltmeter, Multiplying power 1143.

No. of Obn	Amp: in field	Amp: turns on each field coil	MMF on magnet circuit	Cardew volts	Calculated effective ms	Max: ENF on assumption of pure sine wave	Useful flux per pole	Reluctance of circuit	Unit flux density per sq. in.	Reluctance of air.		
1	9	2157	6176	45	514·6	7277	4·93×10⁶	1·25×10⁶	4·44×10⁶	1·39 X10⁻²		
2	10	2730	6862	50	571·5	898	5·48	1·25	4·93	1·39		
3	11	3003	7550	55	629	8804	6·03	1·25	5·49	1·375		
4	12	3276	8234	62	709	1002	6·91	1·24	6·115	1·35		
5	13	3550	8924	68	777	1099	7·45	1·20	6·708	1·33		
6	14	3822	9610	72	823	1164	7·89	1·22	7·104	1·35		
7	15	4094	10290	77	881	1246	8·448	1·22	7·606	1·35		
8	15·5	4231	10630	81	926	1310	8·88	1·20	7·996	1·33		
9	16	4367	10980	87	995	1407	9·574	1·15	8·586	1·28		
10	17	4641	11670	90	1029	1455	9·87	1·18	8·880	1·32		
11	17·5	4777	11990	93	1063	1503	10·2×10⁶	1·18	9·174	1·31		
12	18	4914	12350	98	1121	1581	10·75	1·22	9·650	1·28		
13	18·75	5118	12880	106	1212	1714	11·63	1·21	10·460	1·23		

The machine was operated at various loads but at 10.43 the conditions were :-

Obn	Amp: in field	Amp: turns on each field coil	MMF on magnet circ.	Cardew volts Arg.	Calculated effective r.p.d.	Max: ENF on assumption of pure sine	Useful flux per pole	Rel. of circuit.	Apparent efficiency on watt hours	Brush contact drop	Energy output kilowatts
1	18·25	5090	12800	98	1121	1760	1·075		27	35·1	3934
2	18·0	4914	12350	90	1029	1616			32·3	42·0	4320
3	18·0	4914	12350	93·5	1070	1681			31·6	41·1	4400

The pressure on the field was 110 v. so that the res: of the field (warm) was 6.11Ω (cold 5·75-) At 11.10 one of the iron armature bands of phosphor bronze wire (5 turns in each band) burst with a loud report, and the armature expanded until it touched the field. This threw off the belt and hopelessly damaged the armature.


Thomson-Houston recording Wattmeter
Type 1½ 50 v. 30 amp. rheostat on a 50 v.
continuous current circuit 17th-18th Apr. 91
Watts supplied through meter
Revs. of armature per minute.
0
10
20
30

Tests of Thompson-Houston Wattmeter 17th April 91.

Two of these instruments were tested, marked #31474 and #4817. They are intended for 50-volt alternating-current-work.

The armature of these motors are in series with a resistance and the field are connected across the supply mains. The resistance in circuit with the armature is 31140 in one and 33140 in the other. The resistance of the armature itself is 1140 in one 1370 in the other. The field coils are in series with the load, and have a resistance of 0.01030 in one and 0.01220 in the other. The machine being intended for 50 volts and 30 amps the drop at full load is about 0.31 to 0.37 volt.

The worm on the armature shaft engages with a wheel of 100 teeth whose pinion has 10, and four armature wheels with disks on them complete the train-work. Consequently the motor makes one rev. for 1 hour per watt. or 1 r.p.m. means 60 watts (1 horse power 3600 watts)

The copper disk forming the magnetic brake is 13.32 in diam. and 0.163 thick. It weighs 210 gms.

The magnets of which there are three on each disk weigh 440 gms., are 11.3 in total length, 4.5 in total height 3.18 in uniform width 0.68 thick uniformly and have a square field 3.18 × 3.18 with 0.62 perpendicular distance.

The armature has a diameter of 5.75, a height of 3.5, rising in the center to 4.65, and the weight of armature and spindle together is 110 gms. The total weight of the moving mass is therefore 320 gms.

The following observations were made, with three meters in series with their armatures directly connected in parallel.

No. of Obs.	Ohms	Amp.	Volts	Watts	R. p.f.	R.p.s. per watt			Rev.s	Rev. per Watt	Watts per R.p.m.	R.p.m.
						No. 4817						
1	2.18	11.26	49.5	557.3	0.8163	2.981x10⁻³			0.11449	2.601x10⁻³	384.5	8.694
2	4.15	21.64	120.5	2608	0.6060	2.324x10⁻³			0.6525	2.396	417.4	37.5
3	3.4	17.73	123	2181	0.4525	2.075			0.4938	2.265	441.5	29.63
4	1.56	8.136	72.2	567.5	0.10285	1751			0.1325	2.225	449.4	7.95
5	~~0.1550~~ 0.1500	0.782	52	40.67	~~0.006555~~	ditto			0.005258	1.613	620.0	0.3935
6	0.115	0.5996	44	26.38		"			0.003216	0.731	1368.0	0.193
7	~~0.099~~											

No. of Obs.	#31474 Repetition of Test under more favorable conditions 18th Apr. 91. Ohms	Amp.	Volts	Watts	R.p.f.	R.p.s. per watt	No. of R.	Seconds	R.p.m.
1	1.047	5.461	51.14	280.8	0.06796	2.421x10⁻³	40	588.5	4.078
2	2.112	11.02	49.6	546.6	0.1394	2.551x10⁻³	40	287	8.362
3	2.812	14.67	46.0	675.0	0.17621	2.611x10⁻³	40	227	10.57
4	1.350	7.04	51.2	360.5	0.08997	2.496 "	40	414.5	5.398
5	0.825	4.30	52.9	227.5	0.05749	2.382	20	369	3.252
6	0.486	2.535	52.0	136.9	0.033356	2.451	10	298	2.014
7	0.277	1.445	53.6	77.4	0.01773	2.291	5	282	1.064
8	0.129	0.673	52.8	36.9	0.002283	0.6187	1	438	0.137
9	0.090	0.469	52.0	25.8	0		stop		0

Determination of the best winding for a battery fan motor of 4 cells using the Edison Lalande cells and the worn work of the Edison 1/16 H.P. motor, now at Schenectady

4 cells = 2·8 volts. E.M.F. Allowing electrical efficiency in the circuit for the armature at 0·4 = 1·12 volts generated by armature. The flux in armature = 30,000 and the speed 600 r.p.m. = 10 r.p.s. ∴ to be that the number of turns must be $1·12 \times 10^8 / 3·0 \times 10^6 = 373$, say $42 \times 8 = 336$, or $42 \times 9 = 378$.

The winding space in each groove after deducting insulation is 0·22" broad by 0·24" deep. Each wire must therefore be $\frac{0·22}{9} = 0·073$" diam. covered = 0·060". The nearest is #17 B.W.G. 0·058" and 0·003 51" per foot. Each turn averages about 0·25' so that the length of wire = 99' and its equivalent resistance is $25 \times 0·00351 = 0·088$ ω., with German silver connections this might be increased to 0·1 ω.

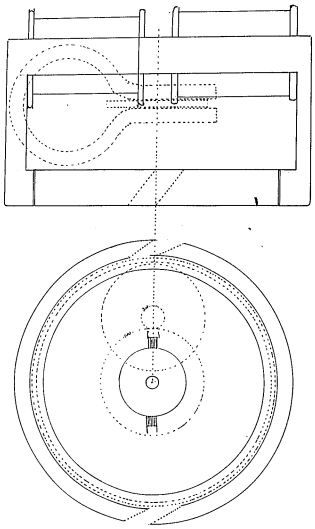
Determination of the dimensions for an Edison Electrolytic Balance Meter for Household purposes.

The area exposed on the surfaces of one plate in the present standard meter bottle is 1·5 sq. in: on the inside face, and if the lids be added 0·25 (5) = 1·25 more making a total 2·75 sq. in. = 17·74 sq. cms. of active surface at a distance of 0·25" = 0·635 cm. from the opposite plate. The resistance of this arrangement is 2·5 ω @ 70° F. At ₱8 meter transfers 1 mgm. of zinc for 8 ampère-hrs. = $\frac{8}{0·4}$ = 20 amp.-hrs = 25 ℔. in money value. Such a plate is usually weighed to 5 mgms. and the error is thus less than ₱1·25. But the limit be now reduced to 10 mgms, and let the current through the meter be increased 3 times, at the same time let the resistance of the meter bottle be reduced 10 times. Let the clearance be 1 cm: Then the surface of the cylinder in active use must be $\frac{10 \times 17·74}{0·635} = 279$ ℔ sq. cms.

A cylinder 2·5" in diam: will be 6·35 cms. in diam. and 19·95 cms. in circumference = 14·0 cms. long = 5·5" allowing for hole being cut for circulation = 6" long. If the thickness of the cylinder be 3/32" = 0·24 cm. there will be about 70 c.c. of zinc in the whole cylinder. The sp.g. being 7·2 the mass will 504 gms. in solution of 1·11. the weight will be 1430 gms. or 1 lb.

With half this thickness of metal namely 3/64" = 0·12 cm. there would be a mass of 250 gms weighing 2/5. It would be possible to float this in such a way that only a weight of say 100 gms was sustained by the scale beam. 150 gms. or 110 c.c. of solution would be displaced. The range of temperature would be from 40° F (4·5° C) to 90° F (32·2° C). The expansion of the solution per °C. is (See Book III p.53) 0·075 ℔ per °C. = 27·7 × 0·075 = 2·067 ℔ for the whole range. The mass of 110 c.c. @ 27·7° C elevation of temp. would be 104·9 gms. That is it would gain 3 gms: in weight owing to this range. This large error would necessitate a correction owing to temperature.

Half side section of arc lamp circuit



75 commutator blocks, 150 turns of wire on armature.
Gross section of armature 2.54 X 0.375 = 0.95 sq. cms.
Cross - - field coil 5 sq. cms.
Cross - - field pole segment 2.54 X 1.25 = 3.17 sq. cms.
1 revolution of the armature carries the rod 12 cms. Pitch radius 1.27 cms.
Copper disk 0.325 cms. thick diameter 7.55. geared with armature 6 to 1.
Resistance of armature between brushes 0.2 ω
- - main coil. field 0.02 ω
- - Shunt. - 320 ω

Resistance of a Pilsener arc lamp series coil 0.155 ω
- - - Sperry) - - - - 0.125 ω

Lightning Arrestors for Edison Illuminating Cos.

50 arrestors were received from the Phonograph Work on the 24th April. Of these 11 were lost in heating on 1250 volts, since they broke down under that pressure. Of the remainder, 13 were sent to Scranton, 13 to West Chester Pa and 13 to Piqua O. on the 25th April. Average copy 0.016 ℔ 3 thicknesses paper.

Edison Motor arc Lamp. 23rd Apr: 91.

This motor arc-lamp was first tried on the 23rd Apr. It has an armature of the dimensions shewn on the opposite page. It has a double field winding. The upper half has four layers of 19 turns (76 in all) of # 10 B.W.G. 0.134" cond: to 0.150" and this in the line circuit. The lower half has 40 layers of 178 turns each (7120 in all) of # 31 B.W.G. 0.010" cond. to 0.015". The resistance of this shunt coil is 360 ω cal. The armature is wound with 150 turns (3 per slot) of # 16 B.W.G. 0.068" cond. to 0.081" in one layer, and the commutator has blocks. The armature is also in the line circuit. The shunt coil was found to preponderate in strength, pulling the arc too short. With about 100 ω added, the arc became very steady and the current 9 ampins @ 54 volts.

Evaporation Experiment 22nd april 91.

A quart glass measure was filled with tap water to the quart mark, and a film of paraffine oil about 0.25 thick added. The area of surface was about 70 sq. cms. The vessel was placed over the boiler, and the temp. of the water became about 41° C. No comparative loss could be detected by the eye after 72 hours.

The experiment was continued until the 28th May, and no change could then be detected in the level.

Resistance of Experimental Car Track 24th Apr.

The experimental low-tension car track is ready as far as the Phonograph Fence, all the rail joints being complete. The following are the results obtained. Shut circuit made at different parts

No. of Pts	P.D. at brushes	Ampins	Distance of p.c. along track	Res: of length	Res: from zero point	Res: per foot
1	4.	950	76 ft	0.004473.	0.00195	0.0000262
2	3.	1100	0	0.002728	0	0
3	4	900	59 down	0.004444	0.00166	0.0000281
4	4.25	750	133 -	0.00567	0.00289	0.0000217
5	4.5	675	191 -	0.00665	0.00397	0.0000202
6	5	600	264 -	0.00833	0.00555	0.0000210
7	6	575	301 -	0.00862	0.00584	0.0000187
8	9	0	-	-	-	-

Formula for determining G.S. connections for bipolar dynamos.

If c = the res: in ohms of one armature coil
n = " number of coils
t = " res: of the armature between brushes if without g.s.
R = " " " " " with g.s.
ρ = " " of one g.s. connection

Then $\frac{c+2\rho}{c} = \alpha$ (1)

$\frac{R}{r} = \beta$ (2)

$t = \frac{n}{4}c$ approximately

$R = \frac{n}{4}c + \rho$ if brush rest on 2 + not more than 2 bars always

$\therefore \beta = \frac{\frac{nc}{4}+\rho}{\frac{nc}{4}} = 1 + \frac{4\rho}{nc}$

(1) $\rho = \frac{\alpha c - c}{2} = \frac{c(\alpha-1)}{2}$

$\beta = 1 + \frac{2(\alpha-1)}{n}$

If 3 bars $\frac{2c+\frac{2}{3}c}{2c} = d$

$\beta = \frac{\frac{nc}{4}+\frac{2c}{3}}{\frac{nc}{4}} = 1 + \frac{8\rho}{3nc}$

(1) $\rho = ac - c = c(a-1)$

$\beta = 1 + \frac{8}{3}\frac{\alpha-1}{n}$

Determination of the dimensions for an G.S. Resistance to carry 200 amperes without overheating at a p.d. of 0.2 v.
28th April 91.

The strip will be 3" wide = 7.62 cms, and 0.009" = 0.0229 cm thick. Assume a resistivity of 3.0×10^{-6}.
The resistance of the instrument must be $0.001 \omega = 10^6$ A.E.M.U.
The res: per cm: will be $\frac{3.0\times10^{-6}}{7.62\times0.0229} = \frac{3.937\times10^{-3}}{0.0229} = 1.7193\times10^{-5}$

Allowing 500 eq: cms: per watt and there will be at full load 400 watts = 2000 eq: cms.

$2lw \cdot 7.62 = 2000$ and $\frac{l}{lw} \cdot 1.7193\times10^{-5} = 10^{-6}$

$lw = 1310.5$ $\therefore \frac{l}{lw} = 5.817$

$\therefore l^2 = 1106$ $l = 33.26$

$n = 6$ nearest integer

$l_n = \frac{60}{1.7193} = 28.64 = 11.27"$.

6 plates 12" long 3" wide 0.009" thick in multiple arc.

Particulars of the 10-kw: Sperry arc Dynamo

Resistance of field @ 26° C. 8.76 ω.
" " armature @ 16° C 8.65 ω.

There are 96 commutator blocks, so that the resistance of one section is $\frac{8.65}{96} = 0.36 \omega$.

If the ratio α be made 6 to 8 with 3 bars under the brush, $\beta = 1 + \frac{40}{288} = 1.14$, the resistance of the armature will be increased 14 %. and $\rho = 1.8 \omega$

This represents about 1.25" of #29 B.W.G. 0.013" diam:

With this wire inserted between commutator and armature, about 2000 volts could be obtained from the machine with separately excited field.

There was very little sparking under any condition of load or load.

On the surface necessary to give an armature in order to enable it to deliver its heat freely.

Without attempting the solution of a very complex problem which would be followed in analysing the distribution and disengagement of heat from an armature, the following principles may be admitted:—

Let ds be any element of the surface of an armature.
θ be its temperature elevation above surrounding air.
v . its translational velocity
dh . the heat it imparts by convection to the surrounding air.

Then $dh = a\,\theta\, v\, ds$ where a is a constant depending on the shape and arrangement of the parts.

$\therefore h = a\theta \int v ds$ when θ is uniform.

When the armature section is a rectangle of breadth b and radius R or. running at n revs: per sec:

$$\int v ds = \tfrac{1}{2}\pi^2 bn\,(R^2+r^2) + 2\pi\,(R^2-r^2)2\pi n\left(\frac{R+r}{2}\right)$$

$$= 4\pi^2 n\left\{b\,(R^2+r^2) + (R^2-r^2)\,\pi\left(\frac{R+r}{2}\right)\right\}$$

$$\therefore h = F + c^2\rho = 4a\theta\pi^2 n\left\{b(R^2+r^2) + \frac{R+r}{4}(R^2-r^2)\right\} \qquad (1)$$

If now $(R-r) = b$

we have $F + c^2\rho = 4\,a\,\theta\,\pi^2 n\left[b\left\{(r+b)^2 + r^2\right\} + \frac{2r+b}{2}\cdot b(2r+b)\right]$

$$= 4\,a\,\theta\,\pi^2 nb\left\{\left((r+b)^2 + r^2\right\} + \left(\frac{2r+b}{2}\right)^2\right]$$

nearly $= 4\,a\,\theta\,\pi^2 nb\,(2r+b)^2 = 4\,a\,\theta\,\pi^2 nb\,(2R-b)^2$

so that for two different sized machines having a common value of a

$$\frac{F_1 + c_1^2\rho_1}{F_2 + c_2^2\rho_2} = \frac{n_1 b_1\,(2r_1+b_1)^2}{n_2 b_2\,(2r_2+b_2)^2} = \frac{n_1 b_1\,(2R_1-b_1)^2}{n_2 b_2\,(2R_2-b_2)^2}$$

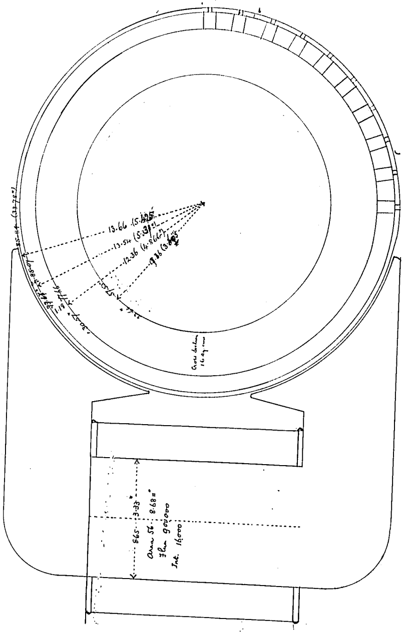
$$= \frac{n_1 b_1\,R_1^2}{n_2 b_2\,R_2^2} \quad \text{about.}$$

Since the peripheral speeds of a series of machines should be constant this reduces finally to

$$\frac{h_1}{h_2} = \frac{F_1 + c_1^2\rho_1}{F_2 + c_2^2\rho_2} = \frac{b_1 R_1}{b_2 R_2}$$

Edison quadripolar 2 Kw. motor section through armature and one magnet.

1/2



Calculations for a 2½ = HP. (2000 = Watt) Edison motor, to run at 1400 r. p. m. on 120 volts terminal p. d.

Referring to the formula on page 130

$V = 2000 \quad \therefore \frac{V}{2\pi} = 318.3$

$n = 1400/60 = 23.33 \quad \therefore R = 13.66.$

With a drop of 0.05 in the armature at full load = 6 volts and a commercial efficiency of 0.7, the intake will be 2000/0.7 = 2860 ÷ 120 = 23.83 } and 6/23.83 = 0.2518 ω hot of which 0.8 or 0.2 ω (hot) may be in the armature proper.

The ohmic loss of energy at full load will be $(23.83)^2 \times 0.2 = 113.6$

Allowing 160 watts lost in Foucaults, and the total H = 275

In the 1 HP. motor H = 200 and Rb = 38.5

$\therefore b_2 = \frac{275}{200} \times \frac{38.5}{13.66} = 3.876$. Say 4 = b = K.

With $B = 14{,}000 \quad \phi = 2 \times 16 \times 14000 = 2 \times 1.6 \times 1.4 \times 10^5 = 4.48 \times 10^5$

$\phi n = 2.333 \times 4.48 \times 10^6 = 1.0452 \times 10^7$

$w = 1.2 \times 10^{10} / 1.0452 \times 10^7 = 1148 \div 36 = 31$ nearest $36 \times 31 = 1116$

31 = 6 layers of 5 + 1 on top.

The mean turn will be 4 × 5 + 2 = 22 cms

The total length of wire will be 22 × 1116/30.48' = 805.5'

The equivalent length - - - - 805.5/16 = 50.35 for 0.2 ω (hot)

Wire has 251.75 feet per ohm @ 100°C = #17 B.W.G. 0.058" covered to 0.071" and the width of groove = 5 × 0.071 = 0.355 + 0.03 = 0.385"

The depth of groove = 6 × 0.071 = 0.426" + 0.04 = 0.466" = 1.18

The total segment of the outer groove circle occupied by groove is 36 × 0.385" = 13.86

- - - - - - - - - - teeth is 19.92' = 0.516"

- - - - inner - - - - - - is 16.71 = 0.464

Arc of polar gap. 30°. Of polar face 60°.

Segment of polar face 14.31 × 4 = 57.25 sq: cms.

Number of teeth carrying flux 6 each 4 × 1.285 = 30.8 sq. cms

Density of flux in teeth = 448,000/30.8 = 14,540.

As this is rather too great an intensity it will be advisable to increase the breadth to 5, and the depth to 3.2

The Polar surface will now be 14.31 × 5 = 71.55 sq. cms.

Density in teeth 448,000/38.55 = 12,620

- - air 448,000/71.55 = 6,260.

Reluctance of air circuit 2 × 0.1/35 = 0.00570

Surface of armature $\pi(13.66^2 - 9.16^2) = \pi(186.6 - 83.9) = \pi(82.7) = 259.8$

259.8 − (36 × 1.18 × 0.85) = 259.8 − 36.1 = 223.7 sq cms × 5 = 1119 c.c.

And 1119 × 7.8 × 9 = 7800 gms. = 17.91 lbs.

The cross section of the field core must be $\frac{2.0 \times 448{,}000}{16{,}000} = 56.0$ sq. cms. 56.0 = 8.68 sq. in.

= 8.45 cms. diam: = 3.327" diam:

Reluctance in iron of circuit 64 cms. of 16 sq. cms. at 15.000 = 4 cms @ 0.005 = 0.025. The MMF required to drive 225,000 lines through this will be 4500 = 3600 A.T. At ⅓ flux the MMF will be 900 A.T.

Estimated weight of this motor 340 lbs. complete.

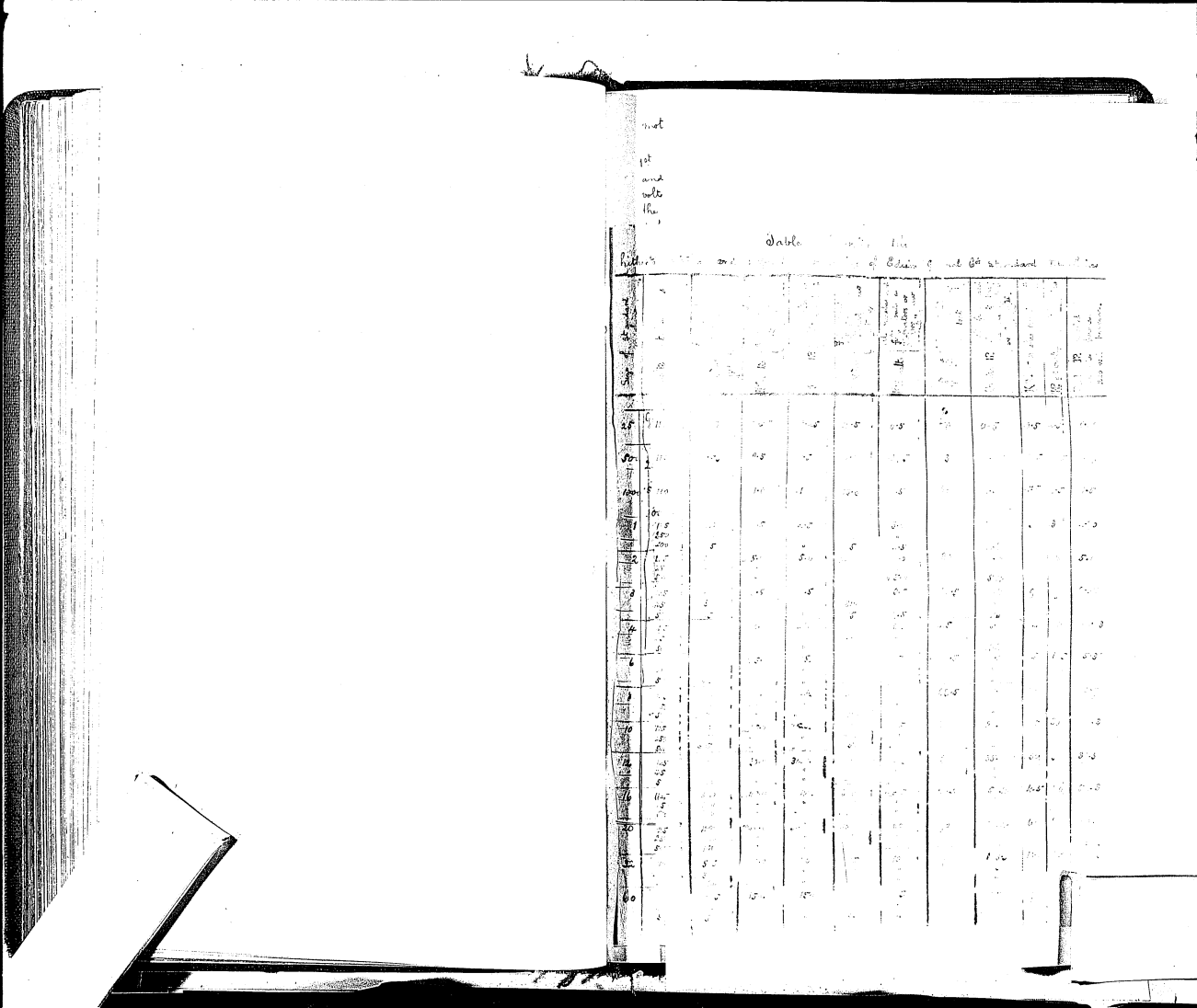
Experiment to determine the amount of Local action in some Edison-Lalande cells left on open circuit 30th Apr: 91.

Four new "C" cells were made up with solution of NaHO in hot engine room water, coods of sp. g. 1.27, and marked nos. 1, 2, 3, 4 &c. Nos. 1 & 2 had plain unamalgamated zincs, nos. 3 & 4 amalgamated zincs. They were weighed in (g) (1/5th grains on the store room scales. These weights are given in grammes.

Name of Cell	Weight 30. IV. 91	11. V. 91	12. V. 91	16. V. 91							
1	102.95	97.03	68.2	52.							
2	99.69	94.77	69.0	66.							
3	113.89	110.0	113.7	112.5							
4	110.64	110.0	112.7	111.5							

"Data concerning 100-Kwt. dynamos tested at Schenectady 1st May 1891.

The engine made 187 rpm. at no load and 165 rpm. at full load. The dynamos delivered steadily 500 amp. each at 128 volts. = 64.0 KW. The full load by design being 666 amp. at 180 volts. About 36 amp. in field. Some sparking at brushes



Conclusions arrived at Concerning the rerating of standard (140
motors for the E. G. E. Co., after interview with Messrs Kunz & Keller
1st May 1891.

That the output of all standard Edison generators for 125 & 250 volts except # 6 & 10 & 12, and all generators for 500 volts except 225 & 12 inclusive should be advanced in rating up to heat limit of their outputs.

That this same increase should be given in each case to corresponding machine when detailed as a motor.

That the power of each motor should be determined by multiplying its rated number of watts into its commercial efficiency determined by actual test.

That the fact of the designed motor pressure being 250 volts, whereas at the present time only 220 volts is generally obtainable, should not cause any change in the rating, but that any complaints made on the score of insufficient pressure should be dealt with individually.

The following are therefore the new ratings compared with the existing ones.

Generator	Volts	Ampères Original	Watts	new Rating Ampères	new Rating Watts	Commercial efficiency	Motor Rated Watts	Brake HP at pressure of Armature (104 volts)	Brake HP of old rating at 110 volts	Brake HP of new rating at 110 volts	Brake HP of 1000 watts rating at 110 volts
											Watts HP
50 Wt	110	2·3	253	4·545	500	0·7	350	0·469	0·25	0·47	1771
	110	4·5	495	6·818	750	0·73	547·7	0·734	0·5	0·73	361·3
	110	9·	990	13·64	1500	0·76	1140·0	1·528	1·0	1·5	762·0
	12.5 / 225 / 200	20 / 10	2500	24·00	3000	0·78	2340·0	3·137	2·5	2·76	1900 2·61
	12.5 / 250 / 200	40 / 20	5000	48·0	6000	0·80	4800	6·432	5	5·66	4000 5·36
	12.5 / 250 / 200	60 / 30	7500	68·0	8500	0·825	7014	9·402	7·5	8·27	6190 8·30
	12.5 / 250 / 200	80 / 40	10,000	96·0	12,000	0·85	10,200	13·670	10	12·03	8500 11·39
	12.5 / 250 / 200	120 / 60	15000	120·0	15000	0·865	12,980	17.400	15	15·31	12,900 17·4
	12.5 / 250 / 200	160 / 80	20,000	160·0	20,000	0·885	17,700	23·73	20	20·87	17700 23·7
	12.5 / 250 / 200	200 / 100	25,000	200.	25,000	0·890	22,250	29·83	25	26·25	22,250 29·8
	12.5 / 250 / 200	240 / 120	30,000	240	30,000	0·890	26,700	35·79	30	31·49	26700 35·8
	12.5 / 250 / 200	320 / 160	40,000	320·0	40,000	0·895	44,300	59·39	40	52·28	44,300 59·4
	12.5 / 250 / 200	400 / 200	50,000	480·0	60,000	0·9	54,000	72·38	50	63·70	54,000 72·4
	12.0 / 220 / 200	675 / 340	80,500	714·3	100,000	0·92	92,000	123·30	80	108·5	92,000 123·3
	14.0 / 270 / 200	1075 / 665 / 300	150,500	1250·0	175,000	0·92	161,000	215·8	150	189·9	161,000 215·8

To Transform the expression $\left(\frac{d^2v}{dx^2} + \frac{d^2v}{dy^2} + \frac{d^2v}{dz^2}\right)$ into polar coordinates, having given

Lightning arrestors for Edison Illuminating Stations.

150 of these finished arrestors, completing the order for 200 see p. 129
These were received on the 2nd May. They were all tested at the full pressure of the municipal machine the same day — about 1250 volts. 6 of them were lost in testing, (principally owing) to faults in the edges of the condensers. This left 144 available.
The following disposition was made of these arrestors.

1	Edison Illuminating Co	Boston Mass.	11
2	" "	Chester Pa	11
3	" "	Scarborough Me	6
4	" "	Birmingham Ala	11
5	" "	Topeka Kans	11
6	" "	Elgin Ill.	11
7	" "	Kansas City Mo.	9
8	" "	Rochester N.Y.	11
9	" "	Lawrence Mass.	11
10	" "	Appleton Wis.	11
11	" "	Des Moines Iowa	11
12	" "	Detroit Mich.	6
13	" "	Philadelphia Pa	6
14	" "	Harrisburg Pa.	6
15	" "	Engineer-in-Chief N.Y.	6
16	" "	retained	6

Total 144.

A Capacity test was made on twelve as follows:—

No.	Capacity	Means	v	v^2	$0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$	$0.8453\frac{\Sigma v}{\sqrt{n(n-1)}}$	Probable error for single condenser	
1	0.016 μf		-2×10^{-3}	4×10^{-6}	$0.2029\times4.472\times10^{-3}$	$0.0736\times12\times10^{-3}$		
2	0.016 μf		-2×10^{-3}	4	$=0.907\times10^{-3}$	$=0.883\times10^{-3}$		
3	0.013 μf		1×10^{-3}	1				
4	0.014 μf		0					
5	0.015 μf		-1×10^{-3}	1				
6	0.012 μf	0.014 μf	2×10^{-3}	4			0.0009 μf	
7	0.015 μf		-1×10^{-3}	1			or 6.4%	
8	0.013 μf		$+1\times10^{-3}$	1				
9	0.012 μf		2×10^{-3}	4				
10	0.014 μf		0					
11	0.014 μf		0					
12	0.014 μf		0	20×10^{-6}				

A distinct shock could be felt from these condensers after having been charged for an hour from after contact with 1250 volts

Weight of field wire per foot 0·098 lb. × 588 = 58 lb. 8 ozs. say 58·5
- - - - on all four spools = 240 lbs.
Diameter covered = 0·192" = 52 turns per layer = 6 layers.
Total copper on field 261 lbs.
Drop in field at full load 28·8 volts.
- - machine - - - 88·8 -

[illegible] OF EDISON, 4 GRADE 15000 WITH CAST STEEL FIELD, 4 MAX.
[illegible] nominal rated for connection of the motor [illegible]
[illegible] Quadripolar armature-ring series wound.
[illegible] To pull a street-car weighing loaded 20,000 lbs. up
[illegible] grade at the rate of 10 miles an hour without undue
[illegible] velocity ratio of the motor and car wheel axles being
[illegible] and the car-wheel having a diameter of 30".
Torque needed at full load 458 ft-lbs. at armature shaft.
Power needed in driving car at full load 12 KW, or 16 HP.
Power [illegible] efficiency 12 KW, or 23 HP. about.
Power at terminals 300, amperes at full load 40.0
[illegible] of armature 250 to 300 rpm.
Peripheral velocity 1500 to 1650 ft. p.m.
Armature dimensions, Diameter over all 21.21"
over conductors 20.0"
over body insulation 19.0"
Core: over body 17.5"
under body 11.25"
Polar bore 10.10" max. 10.0
Clearance .625"
Width of armature above 5 1/2"
below .625"
mean 6"
Gross section of armature core 82.5 sq. in.
Estimated weight of iron in armature 450 lbs.
Armature wire # 17 B&S, 0.045" B.C.C. to 0.071"
850 turns in three layers.
Wire over blocks 250 turning commutator sections
twelfth coil height to commutator sections
four slots wide and three high.
Total weight of wire on armature 350 lbs.
Total length of wire on armature 3500 feet, or 1.1 ohm (hot)
Resistance of armature at full load, [illegible] 0.0 ohms
Loss in armature at full load, [illegible] 2.5 KW.
Field: 4 cores and yokes, [illegible] in all.
Cores 4" diameter and 11" long, in four pieces.
Yokes 4" square, 11" long, 10.5" inside clear.
Weight of cores and yokes 1,250 lbs. each, or 5,000 lbs. in all.
Cores are finished all over and fitted to yokes.
Cores are fastened to yokes by 4 screws in each end and each double.
Cores and yokes have planed surfaces at their connections.
Cores are insulated from yokes by [illegible] fiber or pressboard
Pole pieces of good magnetic cast steel, 10" diameter
Coils and bobbins of good magnetic cast steel, 10" diameter
Coils: length 11", interfacings 10.5" Shaft core 4 1/2"
Coils: 4 in all, 1,250 lbs. on each core 63 lbs. in all.
Coils are divided into 4 sections of 12 turns each.
Coils in series field. All four coils in series, by 4 divided
Coils in series field. All four coils in series, by commutation.
Each coil into three equal parts for commutation.
Each coil into three equal parts for commutation.
Each coil: 36 lbs. of # 7 BWG, 0.180" B.C.C. to 0.19" sq. on each
Each coil: 36 lbs. of # 7 BWG, 0.180" B.C.C. to 0.19" sq. on each
spool; each division 1.5 lbs. 1 making 500 lbs.
spool; each division 1.5 lbs. 1 making 500 lbs.
Coils: four coils, Ampere turns of 12 turns each.
Coils: four coils, Ampere turns of 12 turns each.
Resistance of coils 0.0 ohm, in all 0.0 ohm (hot.)
Resistance of coils 0.0 ohm, in all 0.0 ohm (hot.)
Temperature of coils 210°, about 210°.
Total length of wire on each spool about 1000 feet.
Total length of wire on each spool about 1000 feet.
Watts in field at full load 2000 watts.
Watts in field at full load 2000 watts.
Total weight of copper on field including sheet 250 lbs.
Total weight of copper on field including sheet 250 lbs.
Drop in field at full load, 50.0 volts. in machine 50.0 volts
Drop in field at full load, 50.0 volts. in machine 50.0 volts

Modifications in the Edison 6% grade motor to suit series winding and cast steel field magnets.

Original design see page 1100.

New specification is as follows:-

Bipolar motor series wound to haul a car weighing 20,000 lbs, on a 6% grade at the rate of four miles hour with resistance in circuit. Normal speed at full saturation to be 6 mph. on 30" wheels. 500 volts.

Pull = 1200 + 10×15 = 1350 lbs. at car axles = 1698 ft-lbs = 337.6 ft-lbs. at armature shaft = 153.1 kgm. ft = 1.668×10^6 cm-gms. = 4.58×10^2 kgm-cms

6 m.p.h. = 67.2 r.p.m. of car wheel

Gearing ratio 5 : 1 = 336 r.p.m. of motor say 360 = 6 r.p.sec.

Same flux as in previous design 2.4×10^6 from each pole

$\frac{5}{\text{Total}} \times 10^3$ = 3473 wires say 3360

Commutator blocks, and armature sections 280, 12 wires per section.

Gramme-ring armature continuous winding.

Diameter of armature body over insulation 28.0" Core: 8"

Allowing d.g. factor of winding = 79.2" ÷ 1820 = 0.0707" and allowing 0.0127" for d.c.c. = 0.058" bare copper wire = #17 B&S Gc 3369 c.m.

Height of winding 3 × 0.071 = 0.213", diameter over wire 28.426"

Diameter over binding wire 28.606" 0.09" for binding

Clearances ⅛". Polar bore 28.981".

Resumé of dimensions. Body: int: diameter 21.15" 66.44 53.72 168.7

ext: " 27.90" 87.65 70.86 222.7

over insulation 28.00" 87.96 71.12 223.4

" conductors 28.426" 89.3 72.2 226.8

" binding 28.606" 89.86 72.66 228.3

of polar bore 28.981" 91.04 73.60 231.2

Entrefer 0.54", 1.37 cm.

Mean turn = 1.92' and 3360 turns = 6452' ÷ 16 = 403' equivalent

= $4.03 \times 3.952 \times 10^{-1}$ = 1.6 ω hot (100°C) allowing for 3.2 say 1.75 ω.

6452 × 0.0102 = 65.8 lbs. of wire.

Drop in armature at full load 1.75 × 34.3 = 60.0 volts.

Energy " " " " 34.3 × 34.3 × 1.75 = 2058 watts.

Entrefer at full load assuming full flux thro armature

3.43 × 3.36 × 10^3 × 2.4 × 10^6/6.283 = 14403 × 10^3 cm-lines = 1.469×10^6 cm-gms

= 1.473×10^5 ft-lbs. = 3.247×10^2 ft. lbs. at armature shaft = 16.235×10^2 ft lbs. at car axle = 1280 lbs. at axle.

Cores and Keepers of cast steel. Density 14,000 l = 1.5 3.6×10^4 lines in each core $\frac{3.6}{1.4} \times 10^4$ = 2.57×10^4 = 257 sq.cms = 18.1 equiv. diam.

= 7.13" diam. = 39.6 sq.in. Length 11" = 27.94 Entrefl. 10.5" = 26.67

Thickness of copper 3/16" = 0.476 Diameter over copper 7.505" 19.05

Volume of copper sheet on each core 3.14 × 0.476 × 27.94 × 19.6 = 777 c.c.

777 × 8.9 = 6196 gms = 15.25 lbs. and on all four cores 61 lbs.

Spool diameter internal 7.7"

Magnetic circuit	Armature	Length 40	Cross section 32×6	μ/μ 632	ℰ 8000	℘ 0.001	ℛ 0.00792
	½ Cores	150	128	632	14000	0.0015	0.01185
	Entrefer	2.74	1420	0.00237	"	"	0.006237
						Total	0.0198558

To force 1.2×10^6 lines through a reluctance of 8.85×10^{-3} needs 19,920 mmf = $\frac{19920}{2}$ amp turns. on each spool = 2220 turns of 24 amperes allowing double.

With 1000 Watts expended in the field at full load we have

$\frac{1000}{(37.5)^2}$ = 0.84 ω as full res: hot = 0.21 ω per spool, and the mean turn = 8.4" × 3.14/12" = 2.2' = 528' for 0.21 ω = 2516' per ω = #7 B&S 0.1895

...A OF EDISON OX CRANE STREET-CAR MOTOR WITH CAST STEEL FIELD
...original data a sod combination of Sod. Mar-ch 1911.
...quadripolar gramm ring series wound.
...K to pull a street-car weighing 20,000 lbs. up a 5% grade
...the rate of four miles an hour without overload.
...rque needed at full load 380 ft-lbs. at armature shaft.
...ower needed in driving car at full load 12 KW, or 16 HP.
...lowing 70% efficiency 17KW, or 23 HP. absorbed.
...ltage at terminals 500, Amperes at full load 34.4
...eed of armature 250 to 700 rpm. Peripheral velocity 1900 to
...4320 f.p.m. Velocity ratio of car and motor axles 5.
...iameter of car wheel 40".
...ain dimensions:-Diameter over all 28.62"
over commutators 28.48"
...over insulation 28.07"
over body 27.79"
inside body 1[illegible].07"
...Pole body ...
...Length: ...
between ...
...ross section of armature core 28.62 sq. in.
...stimated weight of iron in armature 370 lbs.
...ain re...: # 12 B&S, 0.0[illegible]" d.c.c. to 0.07[illegible]" ...
...o.m.f. per 120 c.m.s. per ampere at full load.
...esistance of armature not including german silver wires, ... ohms.
...op in armature at full load 38 volts. Energy lost watts.
...mmutator blocks 260 Winding consists gramme ring ...
...half-turn brought to commutator. Sections three wires
...A. and four B. wires, 3360 wires in all in 6 layers
...[illegible] ... on armature 1320 Weight 8[illegible] lbs.
...[illegible] ... from wires and each double
...[illegible] ... and as ... [illegible]
...[illegible] ... 120 wires ... [illegible]
...[illegible] ... in each stack 1.[illegible]" in 240 ...
...[illegible] ... Shank copper 2.[illegible] or 1.82 ...
...[illegible] ... coils in series by each core
...[illegible] ... for commutation.
...[illegible] ... to 0.[illegible] on each core
...lbs. of ... 0.[illegible] wires ... making 200 lbs. in all. About
...[illegible] ... lbs. Making ... lbs. of
...[illegible] ... 2 wires each. Depth of winding 1. [illegible]" of
...[illegible] ... 0.91 dia. in all 0.[illegible] dia. (hot).
...[illegible] ... in each spool about 10'
...total length of wire on each spool 1000 watts.
...ing in field at full load including shoes 241 lbs.
...total weight of copper on field including wires in ...
...[illegible] ... of 1[illegible] load ... [illegible]

Fresh modifications in the 6½ grade motor to suit 2½ armature, the polar bore of which is 24" in diameter.

			cms.	mms.	units
Diameter of polar bore	24"	.	75·4"	60.96	191·5
Clearance ¾"	0·1875"				
Diameter over binding	23·625"	.	74·22"	60·01	188·5
Binding thickness 0·075"					
Diameter over conductor	23·485"	.	73·78"	59·66	187·4
Conductor 4 wire	0·077"-0396		22·89"	58·09	182·5
Insulation	~~0·05~~ 0·014"				
Diameter over body	22·789"	.	71·60'	57·88	181·8
Depth of body 3·375"					
Diameter under body	16·039"	.	50·4"	40·74	128·0

26214 / 1301 / 1323

Allowing winding factor of 0·9 upon the insulation circumference 64·71" which divided by 84·0 gives 0·077", and allowing 0·013" for insulation yields 0·064" for the wire = #14·8 S.W.G. 4·109 c.mils. or 119·8 X 34 = 480 c.mils. per ampere. at 34·37 full load.

290 Commutator blocks. 3360 wire in 4 layers of 840, winding 4" high 3 wide.

Magnetic circuit.

	L	B.	S/A	ℓ	ρ	R.
Entrefer 1·54 cm	1·54	640/2	0·0648	-	-	0·0048 / 0·0048
Cores and poles	150	128	1·2	44,000	0·0015	0·0018
Armature	40	126	0·32	8,000	0·003	0·001
						0·0124

To force 1.2×10^4 through 1.24×10^{-3} needs MMF = $148 \cdot 8 \times 10^4$ = 11840 A.T. = 5920 A.T on each spool. Provision is made for 8000 A.T at full load.

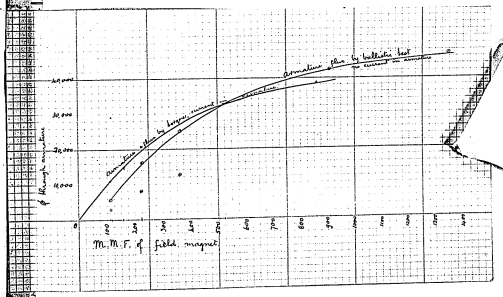
The equivalent length being $\frac{2 \times 3360}{16}$ = 420' and res. per foot 3.238×10^{-3} = 0·136 = hot and g.s. wire may increase this to = 16Ω.

The weight of wire = $2 \cdot 0 \times 3360 \times 0.012465$ = 83·6 lbs.

The drop at full load is $0.16 \times 34 \cdot 3$ = 54·9 ω energy 1883 watts.

The area of armature annulus is 1323 sq.cm $\times 17 \cdot 8 \times 5 \cdot 3$ = 12448 kgms. = 275 lbs.

$$\phi = \frac{2\pi}{CnS} \quad \frac{6.283}{15K} \frac{L}{C} I = \frac{0.4188\ T}{C}$$



Test of Lee-Fuller cells commenced 7th May 91.

Two of these cells were set up on the 7th May according to makers directions as follows:—

Solution in outside cells 2.98 c.c. of H_2SO_4 sp. g. 1.65 - 492 gms.
$Na\ CO_3$ 170 gms
H_2O 1600 gms.

- Inner porous cell with zinc plumb bob $NaCl$ 80 .
H_2O 400 .

Weight of zinc #2 512 gms (1 lb. 9.00 gms) Zinc #1 538.1 gms (1 lb. 1152 gms)
E.M.F. of cell no 1. 2.068 volts P.D. on 2 " 1.82 volts
- - 2 2.060 - - - 1.80 -

May 20th Weight of zinc #1 420 gms. #2 443 gms
June 12 " - - - 360.5 - 385.5 -
July 16th - - - - 312 - 340 -

Test of Arc lamp motor 7th May 91.

1st Test sent a steady current of 8.33 ampères through the armature and a variable current through the coarse winding of the field. By means of a scalepan and weights suspended dirty as string over the commutator, measured the torque produced as follows:—

	Wheel	Amperes in field coil	Amp. in Tunnel	MMF field coil	Rad. of string	Weight of pan	Weight added	Total weight	Moment couple	Moment degree cms.	Calculated Moment of calculated output	No in cms	
1		0	0	0	0	2.4	2.4	20	44	105	1.03×10^4	5180	2.590
2		0.230	1.199	91.12	114.5			70	94	225.6	2.213 -	11,130	5.565
3		0.325	1.694	128.7	161.7			100	124	297.6	2.92 -	14,690	7.345
4		0.451	2.353	178.8	224.8			150	174	417.6	4.097 -	20,610	10.305
5		1.045	5.448	414.0	520.4			250	274	657.6	6.452 -	32,460	16.230
6		1.735	9.046	687.5	864.2			300	324	777.6	7.628 -	38,380	19.190
7		0	0	0	0			90	114	273.6	2.685 -	13,510	6.755

2nd Constant field varying armature

	Current in field coil amps.	Amp. in Tunnel amps.	MMF field coil	Current in field Shunt	amps.	Weight added	Total weight	Moment couple	Moment degree cms.	Calculated	Moment per amp.	
1	0.262	0.2608	35.03	414.03	2.20-362	3.505	0	24	57.6	5.67×10^3	$\frac{5}{4}$ 4860	1.214 $\times 10^3$
2	0.1228	0.9247	70.27	88.3			20	44	105.6	1.036×10^4	46,900	1.121 -
3	0.1653	1.395	106.0	133.2			40	64	153.6	1.507 -	45,220	1.081 -
4	0.4286	3.226	245.2	308.2			100	124	297.6	2.92 -	37,900	0.905 -
5	0.5774	4.348	330.3	415.2			120	144	369.6	3.626 -	34,930	0.834 -
6	0.9163	6.90	524.4	659.2			180	204	489.6	4.991 -	30,300	0.723 -
7	1.0724	8.074	613.6	771.3			200	224	537.6	5.274 -	27,360	0.653.
8	0.360 (block)	1.877	142.6	179.2	Resp. 0.1638	1.233	0	24	57.6	5.65×10^3	13,600	5.01×10^3
9	0.724	3.775	286.9	360.6		1.2071 measured	20	44	105.6	1.036×10^4	11,500	2.705 -
10	1.1444	5.965	453.6	570.2		94.3 grm	50	74	177.6	1.742×10^4	12,230	2.920 -
11	1.522	7.936	602.2	758.2		119.2 mm	70	94	225.6	2.213 -	11,650	2.788 -
12	1.860	9.695	1276.	1604			90	114	273.6	2.684×10^4	11,600	2.769 -
13	2.220	11.575	1523.	1914	0.1673	1.260	100	124	297.6	2.920 -	16,570	2.523 -

Theory of the lamp

Let ϕ be the circuital flux passing through the armature C.G.S.
β . . current in the mains circuit abt.
v . . pressure on the lamp terminals abt.
n . . turns on the series winding
N . . . . shunt -
r . . res: of armature
ρ . . effective reluctance of the magnetic circuit.
w . . mass carried round the armature
g . . gravitation force on the upper carbon dyne
m . . mass of - - - gms.
f . . frictional force . . . = $\frac{1}{100}$ wg gms
r . . radius of pitch section of the lifting pinion cm
l . . length of the arc cms

Then when the current is started through the lamp
we must have $\frac{\phi w}{2\pi} > mgr(1+\mu)$

or $\frac{4\pi^2 nw}{2\pi\rho} > mgr(1+\mu)$

This being the case the carbons will separate.
Leaving out of consideration the kinematical analysis of the motion, assume that the arc becomes steady at a length l such that :—

$$\frac{\phi w}{2\pi} = mgr$$

where $\frac{4\pi}{\rho}\left(\beta n - \frac{4\pi}{r}\beta N\right) = \phi$

$$\frac{4\pi}{\rho}\left(\beta n - \frac{v}{r}N\right) = \phi = \frac{2\pi mgr}{w}$$

$$\text{say } \beta n - \frac{v}{r}N = \frac{mgr\rho}{2w}$$

Let $v = \alpha + \beta l$

$$\beta n - \frac{N}{r}(\alpha+\beta l) = \frac{mgr\rho}{2w}$$

The variation torque for a change of δl is

$$\frac{\delta T}{\rho}\left\{\beta n - \frac{N}{r}(\alpha+\beta l)\right\} w = T$$

$$\frac{dT}{dl} = \frac{2}{\rho}\left(-\frac{N}{r}\beta\right)w = -\frac{2w}{r\rho}N\beta$$

which for proper regulation should be as large as possible. That is to say its mmf should be as great as possible, and consequently the opposing mmf should be as great as possible. There should thus be as many turns as possible on the series coil, with very powerful damping to resist the variation of motion accelerations.

(146)

Test of Arc-lamp continued.

Magnetic circuit test as follows:—

Ref No.	Source of EMF	E.M.F	Lag	Throw	a	
1	1 B.c. 17°c	1·4358	1φ	103	1.4358×10^{-8}	1.394×10^{-9}

Ref No.	Current thro' mec: field		Amp turns	mmf	Throw	a	Res: of G	φ	$\frac{\phi}{a}$ (1)	Total mmf for 2φ		
	Obsvd.	amp.										
1	0·24	1·251	9508	119·5	14	5.576×10^{-8}	5.25×10^{8}	2.927×10^{8}	2,950	5850		
2	0·452	2·387	1791	225·1	11	1.538×10^{-8}		8.05×10^{8}	5850	16,100		
3	0·73	3·806	289·5	363·9	17	2·37 -		1.244×10^{8}	8,290	24,880		
4	1·82	9·149	721·2	906·14	29	4·043 -		2·128 -	14,250	42,460		
5	2·70	14·08	1070.	1345	32	4·461 -		2·342 -	15,620	44,840		
6	5·20	27·10	2059	2588	32·5	4·531 -		2·379 -	15,860	47,580		

Data for a new arc lamp design.

The weight of the rod is 500 gms and the carbon of present length 50 gms. With increased length of carbon, and the loads on the rod necessary to ensure the weight of carbon being relatively small, the total weight to be lifted will be 750 gms. The pitch radius of the rack is about 1·27 cms, so that the gravitational moment is 950 cm-gms, with no friction.

With 1·76 sq: cms: of armature cross-section and a density of 14,000 gauss as useful flux of $3.5\times14,000 = 49,000$ say 50,000 lines. = ϕ

9 ampires and 150 turns on the armature give as moment of

$$\frac{5.0\times10^{14}\times 0.9\times 1.5\times10^{2}}{6.165\times10^{5}} = 1095 \text{ cm: gms: say } 1100.$$

The armature surface is opposite to each pole 22·5 sq: cms, with an entrefer of 0·1 so that the reluctance in the air gap is $\frac{0.2}{22.5} = \frac{1}{112.5} = 0.00886$, and in the whole circuit 0·01 at low saturation so that 4 force 50,000 lines through this needs 500 mgb = 400 AT. = 4ll turns. Allow 100.

At low saturation the variation in torque would be proportional to the current, so that a change of one amp: in the main ckt: would vary the torque about 120 cm: gms.

The cross section of the magnets has to be 3.5 sq: cms: for useful lines 5.07 for leakage

Check 1° has a diam: of 2·54 cms and an area of 5·067
its surface per cm: is 3·14116 × 2·54 = 7·98 cms, and it cms therefore
deliver $\frac{7.98}{20}$ = 0·399 watt.
Its rec: per cm: is $\frac{2·0 \times 10^{7}}{5·067}$ = 0.395×10^{7} abs. units = 3.95×10^{6}
and the heat from 318 amps will be $101100 \times 3.95 \times 10^{-6}$ = 1.01×3.95 ki

...067
therefore
...5×
...5×10³
...01×3·95×10⁻³

TABLE OF THE RESISTANCE AND CURRENTS CARRYING CAPACITY OF GALVANISED IRON WIRE ENCLOSED IN VENTILATED CHAMBERS. 8th. MAY 1891

Nos. Gauge	Diam. Inches	Ohms per Mile	Ohms per Ft.	Amperes.
5	0.1813	34086	0.00645	24.7
6	0.1642	26244	0.00435	20.8
7	0.1483	20832	0.00549	17.5
8	0.1285	16512	0.00692	14.8
9	0.1144	13067	0.00873	12.8
10	0.1019	10364	0.01103	10.3
11	0.091	8226	0.0139	8.7
12	0.0808	6529	0.0175	7.3
13	0.072	5184	0.0221	6.2
14	0.0641	4109	0.0278	5.2
15	0.0571	3260	0.0351	4.5
16	0.0508	2581	0.0442	3.7
17	0.0453	2052	0.0555	3.1
18	0.0403	1624	0.0704	2.6
19	0.0359	1289	0.0887	2.2
20	0.032	1024	0.112	1.8
21	0.0285	812	0.141	1.5
22	0.0253	640	0.178	1.3
23	0.0226	511	0.225	1.1
24	0.0201	404	0.283	0.9
25	0.0179	320	0.357	0.76
26	0.0159	253	0.450	0.64
27	0.0142	200	0.569	0.54
28	0.0126	159	0.626	0.48
29	0.0113	128	1.02	0.34

The resistances in column 4 are the resistances per foot of the wire at 100° Centigrade. This can only be regarded as approximate since different samples of iron wire vary both in resistivity and temperature coefficient.

The currents in the last column are the limiting currents that each wire can safely carry when enclosed in a small ventilated box, and are such as will bring the temperature of the wire from 20° to 100° degrees Centigrade above those conditions. When the ventilation is imperfect, the same limit of temperature may be reached with perhaps only one third of the current strength tabulated.

Data for the heating of iron wires in resistance boxes

will probably be safe to allow 26 cgs ems: per watt, and as resistivity of 5×10^{-5} at 100° C.

Calling ρ the resistivity at 100° C
r . rad: of the wire
e . emissivity per sq cm: of surface abs: exp per sec:
c . current in abs: measure

$$\frac{c^2\rho}{\pi r^2} = 2\pi e r$$

$$\therefore c^2 = \frac{2\pi^2 e r^3}{\rho}$$

$$c = \pi\sqrt{\frac{2e}{\rho}}\, r^{\frac{3}{2}} \quad \text{with } r \text{ in cms}$$

$$\gamma = 10\pi\sqrt{\frac{2e}{\rho}}\, r^{\frac{3}{2}} \quad \ldots \quad \gamma = \text{amperes}.$$

$$\gamma = 10\pi\sqrt{\frac{2e}{\rho}}\,\frac{r^{\frac{3}{2}}}{(2.54)^{\frac{3}{2}}} \quad \ldots \quad \text{inches}.$$

$$= 3111.16 \times \sqrt{\frac{2\times 2.283\times10^{6}}{18\times10^{10}}} \times (2.54)^{\frac{3}{2}} \times r^{\frac{3}{2}} \times 10$$

$$= 3.1416 \times \sqrt{50} \times 4.05\times10\, r^{\frac{3}{2}}$$

$$= 3.1416 \times 7.07 \times 4.05 \times 10 \times \frac{d^{\frac{3}{2}}}{2.828} \quad \text{where } d \text{ is in inches}$$

$$= 318.2\, d^{\frac{3}{2}}$$

Diam:	$D^{\frac{3}{2}}$	γ	Res: Pot: per foot	No. B.W.G.	Drain	$D^{\frac{3}{2}}$	γ	Res: Pot. per foot.
.819	0.077752	24.766	3.453×10^{-3}	19	0.03589	0.006805	2.765	0.08873
.762	0.066245	20.982	4.354 "	20	0.03196	0.005716	1.819	0.1119
.1143	0.054587	17.146	0.005349	21	0.028446	0.004901	1.528	0.1411
.1088	0.0546	14.64	0.006972	22	0.02535	0.004035	1.284	0.1781
.1144	0.0386	12.28	0.008730	23	0.02257	0.003389	1.079	0.2246
.1019	0.0325	10.34	0.011401	24	0.0201	0.002851	0.907	0.2828
.1907	0.02733	8.695	0.01386	25	0.0179	0.002395	0.762	0.3572
.1808	0.02297	7.309	0.01750	26	0.01594	0.002201	0.6396	0.450
.1720	0.01934	6.154	0.02206	27	0.01419	0.001689	0.537	0.5686
.1681	0.01623	5.164	0.02783	28	0.012641	0.001423	0.453	0.6258
.1571	0.01365	4.343	0.03509	29	0.01126	0.001194	0.380	1.015
.1508	0.01145	3.643	0.04424	30	0.01003	0.001005	0.320	1.137
.1453	0.00965	3.071	0.05580	31	0.008928	0.000844	0.267	1.434
.1403	0.008096	2.577	0.07038	32	0.00795	0.000709	0.226	1.814

The res: per cm: = $\frac{\rho}{\pi r^2}$ where r is in cms

$= \frac{\rho}{\pi r^2 (2.54)^2}$ . . . . inches

$= \frac{6.45}{4}\pi d^2$ . . . d . . . inches.

$= \frac{1.5\times10^{-5}}{5.222\, d^2}$ . . . . .

$= \frac{4.877\times10^{-5}}{5.222\, d^2} = 0.845\times10^{-5}\left(\frac{1}{d^2}\right)$ ohms per foot: res.

Test of a small two bladed fan motor from Silvertake 8th May 1891. on Edison Lalande cells.

These cells used to drive this were of the cartridge type
Res. of field 0.224 ω Res. of armature 0.205 ω Total 0.1645 ω

No. of cells	E.M.F.	Int. res. estimated	Res. of motor	Current Work	Current amps	Speed r.p.m.	Counter E.M.F.	Total E.M.F.	Drop in battery	Pd. on motor
1	0.7	0.025	0.1445 ω	.		–		0.1695		
2	1.4	0.09		0.24	2.61	280	0	0.535	0.23	1.17
3	2.1	0.130		0.625	3.26	400	0.225	0.575	0.444	1.67
4	2.8	0.170		0.685	3.57	480	0.600	0.615	0.60	2.2
5	3.5	0.210		0.830	4.33	520	0.660	0.655	0.91	2.6
6	4.2	0.26		0.925	4.824	560	0.80	0.795	1.21	3.0

By last on the 13th June, when the first set of coils was mounted, the starting current at 156 volts was 18 ?
By telegram of the 15th the rise of temp. on the coils was 55°5 after several hours.

11th. May 91

Mr. Ballou :-

Kindly note the following winding for the seven sets of
the separating magnets you are now making for Ogden:-
One set - 16 magnets - 28 spools.
Each spool same dimensions as at present but larger flange
[illegible] Inside flange 15". Internal diameter 5"1/16
Bobbin diameter 3 1/4" Flange diameter 8"1/2
Wire B & S gauge No. 18" covered to 0.105" say.
0.5 lbs. on each spool 225 lbs. on set of 28 spools.
[illegible] will correspond to a length of 718' on each spool
Current 1ajer. 5 3/4 lajers.
Depth of winding 1.2"

Yours faithfully,

A. E. Kennelly.

Determination of the winding for a series of 16 ore-milling Separator-magnets for Ogden N. J. 9th May 91.

The present arrangement is as follows:—

160 volts at dynamo terminals.
155 " " machine terminals.
37 amperes " "
5735 Watts in machine
32 spools
179 watts in each spool.

Amp. turns per spool 46660
" " magnet 13,320
mmf 8872
" 16,705

Dimensions of spool:—

			Circumference	
Length	39.5	1.29'		
Inside flange	38.25	1.25'		
Int: diam:	13	0.1425'		
Winding	13.3	0.442'	40.9	1.336'
Over wire			1st layer 41.8	1.363'
			2nd layer 42.5	1.38'
			3rd layer 50.3	1.65'

External surface of spool 1836 sq. ins.
Internal " " " 1600 " "

10 sq. ins. per watt of external spool surface per watt.
Wire # 8 B.W.G. 0.165" cond. to 0.182". 80 turns per layer = 1.456'-1.21'
Mean circumference 1.5'
Two layers and one quarter 80 turns on the 1st, 80 on the second, 20 on 3rd
180 turns in all = 270' on each spool = 22.6 lbs.
589 lbs: in all and 7150' @ 25¢ = $1147.

New design:—

160 volts at dynamo terminals
155 " " machine "
18.5 amperes
2867 Watts
32 spools
89.6 watts per spool.
4.843 volts
0.2618 ohms . @65°c, 5.378 in all. @60°c.
360 turns demanded 400 allowed
0.18" covered to 0.195" + 0.21" winding or # 7 B.W.G. copper wire.
71 turns per layer
5.75" layers.
1.26" depth of winding.
1.3" over tape.
1.5" between spools.
718' on each spool 23000' in all
70.5 lbs " " 2256 lbs @ $0.28 = $519
Diameter of spool over all 0.96', circumference 2.09' 63.7
External surface 63.7 × 39.25 = 2437 sq. ins.
27.2 sq. ins. per watt.

Balance between #1 strip in meter #13816

1489 ω added to whole grid 0.01491 2

$6525 + 1489 = 8014$

$0.01491 2 \times \frac{6525}{8014} = 0.0139985$

Balance between #2 strip in meter # 21214

1425 ω added to upper half of grid 0.024462 ω

$6525 + 1425 = 7950$

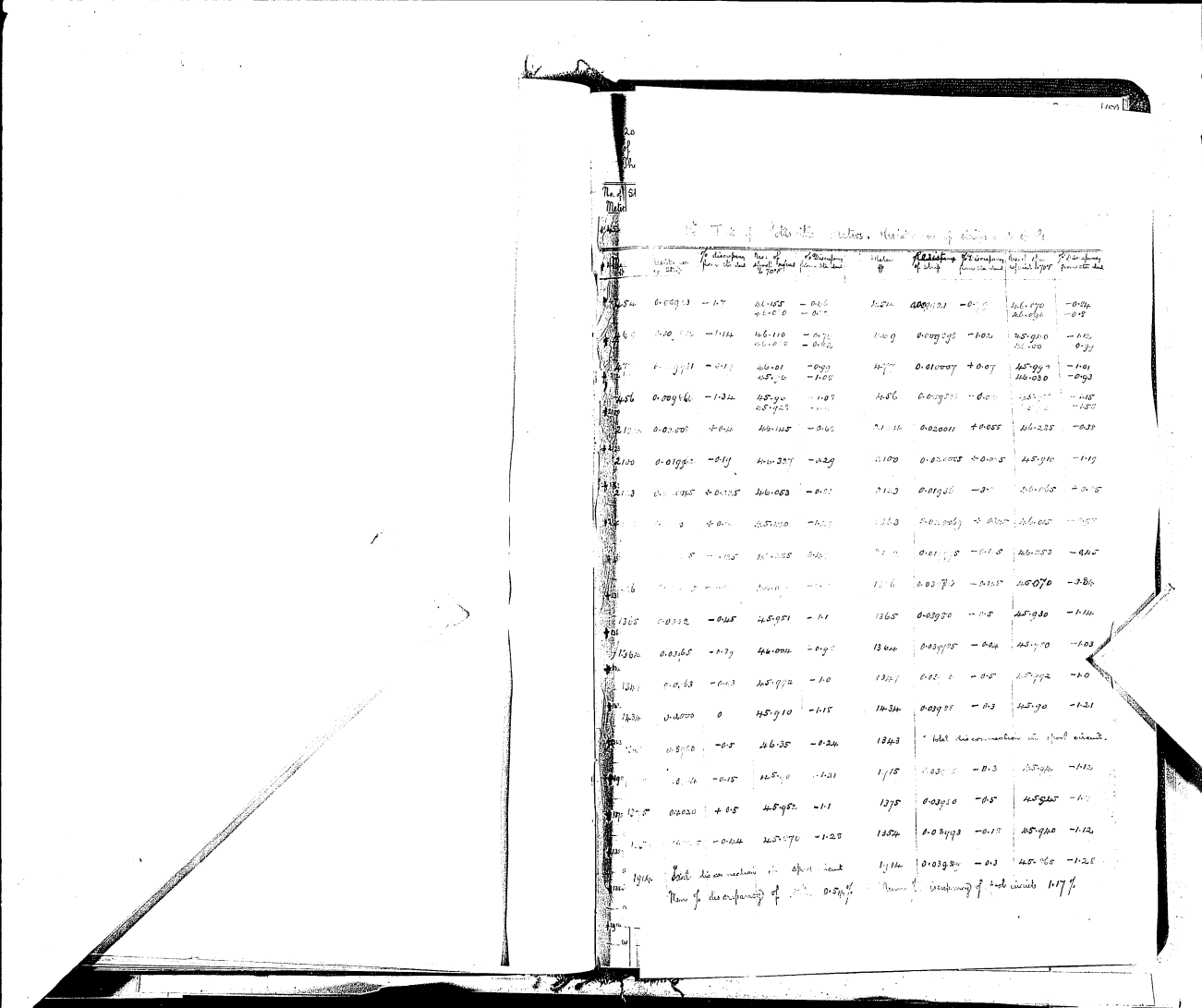
$0.024462 \times \frac{6525}{7950} = 0.020088$ ω

Balance between #4 strip in meter #454

9945 ω added to upper half of grid

$6525 + 9945 = 16470$

$0.0245 \times \frac{6525}{16470} = 0.009703$?



Fuit Test of Pottsville Meters for Edison General Electric Co:

20 meter cases of the new standard 3-wire type were received for test. of these 4 were #4 s. 5 were #2.5 and the remaining 11 #15. They were tested by differential Galvanometer $\frac{130.50}{2}$ ω in each coil.

No. of Meter	Standard	Below of Standard	Res. for Balance	Added to	Ratio	Res. Found of Standard	Res. at 17°C.	Res. of Shunt by check Shunt	Leads + shunt	Res. of spools	Res. of spool Coils	Temp. in + Bridge	Discrepancy	Spool Ratio	Shunt Ratio
		0.09983	0				0.09983	45.419 45.313	0.1161	45.274 45.221	46.155 46.090	TB. 19°C	- 1.7	0.9990	0.46
			60 ω	(A)	$\frac{6585}{6625}$	1.0092	0.099921	45.331 45.323		45.193 45.221	46.070 46.090	Temp of	- 0.79	0.9996	0.26
			37 ω	(1)	$\frac{6562}{6623}$	1.0057	0.099896	45.373 45.316		45.232 45.264	46.110 46.090	in Lt.	- 1.14	0.9994	0.36
			140 ω	(B)	$\frac{6576}{6625}$	1.0069	0.099837	45.316 45.284		45.264 45.284	46.090 46.090		- 1.02	0.9988	0.22
			100 ω	(1)	$\frac{6625}{6525}$	1.0153	0.099781	45.273 45.247		45.284 45.264	46.090 46.090		- 0.19	0.9981	0.09
			117 ω	(2)	$\frac{6643}{6625}$	1.0180	0.0100007	45.267 45.247		45.296 45.264	46.080 46.090		+ 0.07	0.9979	0.01
			23 ω	(1)	$\frac{6504}{6525}$	1.0036	0.099864	45.284 45.247		45.188 45.264	46.030 46.090		- 1.34	0.9993	0.28
			140 ω	(2)	$\frac{6576}{6525}$	1.0069	0.099898	45.195 45.247		45.094 45.264	45.948 46.090		- 1.02	0.9988	0.17
								44.855		44.857	45.725			0.9982	1.57
		0.02088	0				0.02088	45.418 45.264	0.151	45.267	46.105		+ 0.46	0.9992	0.62
			22 ω	(Std.)	$\frac{(6707)}{(6725)}$	0.9963	0.02091	45.583 45.247		45.407	46.285		+ 0.625	0.9962	0.38
			39 ω	"	$\frac{6727}{6564}$	0.9941	0.019962	45.388 45.264		45.447	46.327		- 0.19	0.9971	0.29
			24 ω	"	$\frac{6736}{6704}$	0.9961	0.020005	45.380 45.247		45.029	45.910		+ 0.025	0.9981	0.19
			7 ω	"	$\frac{6732}{6732}$	0.99815	0.020046	45.380 45.247		45.179	46.053		+ 0.223	0.9976	0.08
			250 ω	"	$\frac{6832}{6771}$	0.9631	0.01936	45.340 45.247		45.189	46.085		- 3.2	0.9916	0.82
			0	"	1	1.0	0.02089	45.110 45.247		44.989	45.860		+ 0.44	0.9971	1.09
			4 ω	"	$\frac{6732}{6697}$	0.9994	0.020049	45.240 45.247		45.139	46.015		+ 0.3185	0.9982	0.96
			31 ω	"	$\frac{6823}{6709}$	0.9948	0.019975	45.5285 45.247		45.3584	46.235		- 0.125	0.9951	0.94
			34 ω	"	$\frac{6732}{6709}$	0.9948	0.019975	45.5285 45.247		45.374	46.253		- 0.225	0.9951	0.85
		0.039925	0	0			0.039981	45.330 45.247	0.161	45.159	46.030		- 0.014	0.9997	0.93
			47	Standard	$\frac{6858}{6772}$	0.9928	0.039978	45.3258 45.247		45.804	46.070		0.0751	0.9976	0.80
			28	"	$\frac{6732}{6727}$	0.99755	0.039982	45.240 45.247		45.089	45.951		0.45	0.9969	1.11
			43	"	$\frac{6838}{6768}$	0.99312	0.039820	45.220 45.247		45.836	45.930		0.5	0.9986	1.16
			26	"	$\frac{6732}{6781}$	0.9975	0.039962	45.240 45.247		45.129	46.001		0.89	0.9990	0.98
			0	"	1	1.	0.039981	45.270 45.247		45.109	45.980		0.014	0.9987	1.01
			58	"	$\frac{6735}{6773}$	0.9912	0.039783	45.280 45.247		45.119	45.992		0.93	0.99	1.0
			28	"	$\frac{6732}{6703}$	0.9957	0.039880	45.280 45.247		45.119	45.992		0.5	0.999	1.0
			2 ω	400	$\frac{6832}{6732}$	1.0003	0.040000	45.200 45.247		45.239	45.991		0	0.9982	1.18
			17 ω	Standard	$\frac{(6703)}{(6732)}$	0.9977	0.039958	45.190 45.247		45.029	45.890		0.3	0.9979	1.21
			30 ω	"	$\frac{(6735)}{(6732)}$	0.9954	0.039980	45.463 45.247		45.449	46.35		0.5	0.9976	1.24
			∞	"	∞	∞	∞	∞		∞	∞				∞
			7 ω	"	$\frac{(6732)}{(6732)}$	0.9983	0.039941	45.19 45.247		45.029	45.890		0.15	0.9979	1.21
			17 ω	"	$\frac{(6753)}{(6732)}$	0.9976	0.039958	45.225 45.247		45.96 ω	45.94		0.3	0.9988	1.16
			30 ω	1645	$\frac{(6832)}{(6732)}$	1.0022	0.040022	45.244 45.247		45.079	45.952		0.5	0.9989	1.1
			30 ω	Standard	$\frac{(6735)}{(6707)}$	0.99524	0.039820	45.2245 45.247		45.074	45.9458		0.45	0.9989	1.11
			26 ω	"	$\frac{(6727)}{(6732)}$	0.9948	0.039779	45.415 45.247		45.258	46.130		0.6	0.9994	1.21
			32 ω	"	$\frac{(6727)}{(6703)}$	0.9981	0.039919	45.405 45.247		45.2424	46.120		0.5	0.9987	1.18
			26 ω	"	$\frac{(6727)}{(6732)}$	0.9960	0.039832	45.158 45.247		45.991	45.870		0.424	0.9972	1.25
			11 ω	"	$\frac{(6736)}{(6732)}$	0.9983	0.039933	45.225 45.247		45.064	45.960		0.16	0.9988	1.12
			∞	"	∞			∞							
			15 ω	"	$\frac{(6703)}{(6732)}$	0.9977	0.039899	45.155 45.247		44.991	45.865		0.3	0.9972	1.22

As an important practical example of this calculation, consider the empirical equation of copper conductivity – that for the time we accept as absolute) since – established by Matthiessen

$$\lambda = 1 + \cdots - 0.00338701\, t + 0.00000909\, t^2$$

λ being the conductivity at temperature of $t°$ C relative to that at zero C.

Here $b = -3.8701 \times 10^{-3}$ & $c = 9.009 \times 10^{-6}$

Required the best formulae of the same species for resistances between the temperatures of 0° + 100° C. ($T = 100$, $t = 0$, $\tau = 50$)

$$P = \frac{-0.003\,8701 - 0.000\,9009}{1 + 0.193\,505 + 0.022\,523} = \frac{-0.004\,7710}{1.216\,028} = -0.004\,6664$$

$$\frac{T+t}{2} = \tau = 50$$

$$\frac{T^2 + Tt + t^2}{3} = 3333.3$$

$$d = \sqrt{(3.8702 \times 10^{-3} - 4 \times 9.009 \times 10^{-6})} \sqrt{(14.977 - 36.036) \times 10^{-3}} = -4.5891 \times 10^{-3}$$

$$Q = \sqrt{\frac{1}{-4.5891 \times 10^{-3}}} \log_e \left\{ \frac{(1.8018 \times 10^{-3} \times 10^{-3} + 3.8701 \times 10^{-3} + 4.5891 \times 10^{-3})(3.8701 \times 10^{-3} - 4.5891 \times 10^{-3})}{(1.8018 \times 10^{-3} \times 10^{-3} + 3.8701 \times 10^{-3} - 4.5891 \times 10^{-3})(3.8701 \times 10^{-3} + 4.5891 \times 10^{-3})} \right\}^{-1}$$

$$2.1791 \cdot \log_e \left\{ \frac{1.0261 \times 10^{-2}}{1.0829 \times 10^{-3}} \times \frac{-0.7190 \times 10^{-3}}{8.4592 \times 10^{-3}} \right\}^{-1}$$

Now $ac > b^2$ so that $Q = \left[\left(\frac{1}{T-t}\right)\frac{2}{c}\left\{\tan^{-1}\frac{2cT+b}{e} - \tan^{-1}\frac{2ct+b}{e}\right\}\right]^{-1} + e = \sqrt{ac-b^2}$

$$e = 4.5891 \times 10^{-3}$$

$$Q = 2K2 \cdot 1791 \left(\tan^{-1}\frac{1.8018 \times 10^{-3} + 3.8701 \times 10^{-3}}{4.5891 \times 10^{-3}} - \tan^{-1}\frac{3.8701}{4.5891}\right)^{-1}$$

$$\tan^{-1}\frac{5.6719}{4.5891} - \tan^{-1}\frac{3.8701}{4.5891}$$

$$1.2362 - 0.8433$$

$$51°.2' - 40°.9'$$

$$10°.23'$$

$$4 \times 3582 \times 0.1899 = 0.8278 - 1 = -0.1722$$

$$\begin{vmatrix} \tau & t & \\ 100 & = & +0.0038701 \\ 50 & = & 3333.3 \end{vmatrix} \cdot \Delta = -1666.6$$

$$p = \begin{vmatrix} 0.0038702 & 100 \\ 0.1722 & 3333.3 \end{vmatrix} \div -1666.6 = \frac{13.0773 - 17.22}{-1666.6} = \frac{+4.1427}{1666.6}$$

$$r = \begin{vmatrix} +0.0038702 & 100 \\ +0.1722 & 50 \end{vmatrix} \div -1666.6 = \frac{+0.19316 + 0.1722}{-1666.6} = \frac{+0.03596}{+1666.6}$$

$$p = 2.486 \times 10^{-3}$$

$$r = 1.43777 \times 10^{-5}$$

$$(1 + bt + ct^2 + dt^3)^{-1} = 1 - bt + t^2(b^2 - c) + t^3(2bc - b^3 - d) + t^4(c^2 + 2bd - 3b^2c + b^4) + t^5(2cd - 3b^2d - 3bc^2 + 4b^3c - b^5)$$

With $b = -3.8701 \times 10^{-3}$ and $c = 9.009 \times 10^{-6}$

$$\tau = 1 + 3.8701 \times 10^{-3} t + 5.968 \times 10^{-6} t^2 - 1.177 \times 10^{-8} t^3 - 9.93 \times 10^{-11} t^4 - 2.79 \times 10^{-13} t^5$$

Having given a certain definite physical relationship expressed by the equation $x = a + bt + ct^2$, and supposing that it is required to find an equation of the same form for the reciprocal of x, determine the best value for the new constants in the equation $\frac{1}{x} = p + qt + rt^2$ in order that the accuracy of the equation may be the greatest possible between certain values T and τ of t. (151)

It is always easy to transform these equations into others similar and of the same order but with unity for the first term, so we shall only consider $x = 1 + bt + ct^2$ and $y = \frac{1}{x} = 1 + qt + rt^2$

Let T be a value of t intermediate between $\overline{T}$ and τ and let t be single valued and continuous between these limits.

Then $1 + qt + rt^2 = (1 + bt + ct^2)^{-1}$

Expanding the right hand

$$= 1 - (bt + ct^2) + (bt + ct^2)^2 - (bt + ct^2)^3 + \text{&c}$$

$$= 1 - bt + t^2(b^2 - c) + t^3(2bc - b^3) + t^4(b^4 - 3b^2c + c^2) + t^5(b^5 - 3b^3c + 4bc^2) + \cdots$$

The ratio of the 3rd to the fourth term in this expansion is

$$\frac{-\frac{1}{t}(b^2 - c)}{b(b^2 - 2c)}$$

So that unless $\frac{1}{t}$ is large compared with t the subsequent terms cannot be neglected with impunity. We have however

$$d\left\{\frac{1 + qt + rt^2}{dt}\right\} = \frac{d}{dt}\left\{\frac{1}{1 + bt + ct^2}\right\}^{-1}$$

$$q + 2rt = \frac{-b - 2ct}{(1 + bt + ct^2)^2}$$

$$\therefore r = \left\{\frac{b + 2c\tau}{(1 + b\tau + c\tau^2)^2} - \frac{b + 2ct}{(1 + bt + ct^2)^2}\right\}\frac{1}{2(t - \tau)}$$

$$q + 2\tau r = \frac{-b - 2c\tau}{(1 + b\tau + c\tau^2)^2} \qquad (1)$$

If τ be $\frac{T+t}{2}$ this relation makes the tangent of the new curve parallel to the tangent of the base curve at the mean value of the independent variable.

Since the new second relation, the area between the respective curves and the terminal ordinates and the abscissa axis are to be equal we have

$$\int_t^T (1 + qt + rt^2)\,dt = \int_t^T \left(\frac{1}{1 + bt + ct^2}\right)$$

or $(T - t) + \frac{q}{2}(T^2 - t^2) + \frac{r}{3}(T^3 - t^3) = \frac{1}{d}\log_e\left\{\frac{(2c\tau + b - d)}{(2c\tau + b + d)}\frac{(2ct + b + d)}{(2ct + b - d)}\right\}$ &c. (2)

where $d = \sqrt{b^2 - 4ac}$

Equations (1) and (2) are theoretically sufficient for the evaluation of q & r

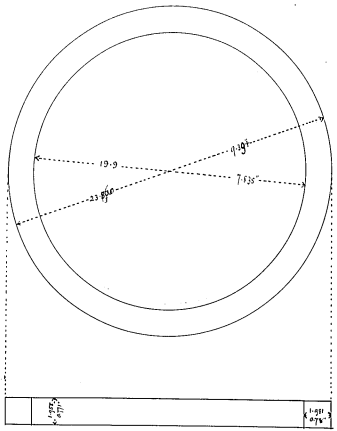
$$\left|\begin{array}{ccc} q & & r \\ 1 & + & 2\tau = P \\ \frac{T+t}{2} & + & T\frac{T+t}{3} + t^2 = Q \end{array}\right| \qquad (3)$$

where $P = \frac{-b - 2c\tau}{(1 + b\tau + c\tau^2)^2} + Q = \sqrt{\frac{1}{d(T-t)}}\log_e\left\{\frac{(2c\tau + b - d)}{(2c\tau + b + d)}\frac{(2ct + b + d)}{(2ct + b - d)}\right\} - 1$

and $d = \sqrt{b^2 - 4ac}$

Test of Sample of Magnetic Steel from The Pennsylvania Steel Co. Steelton Pa. marked no 1.

This casting was an anchor-ring about 1.25" diameter of section. It was turned down in the lathe to a square section, the dimensions being as shewn:- There were many small blow holes in the iron ring.



No of obs	Source of EMF		EMF		Capacity		Q		Mean throw		q per div.		No. of turns					
	1 Ld @ 19.5°c		1.1433		.2 μ		2.866×10^{-7}		202		1.419×10^{-9}		11					
No of obs	Steady	Amperes	Amp turns	MMF	MMF / 4π	No of throws	Mean throw	Run in cent.	Total nos.	q	L	ρ						
1	0.030	0.1564	11.450	1823	26.52	4	3	0	5250	5.58×10^{-6}	1.144	1.814×10^{-3}						
2	0.062	0.318	2941.8	3706	53.92	6	4.53	0	"	8.427×10^{-3}	2.175	3.478×10^{-3}						
3	0.072	0.3754	3480	4374	63.64	4	6.67	0	"	12.42×10^{-3}	3.202	1.987×10^{-3}						
4	0.085	0.4453	4128	5189	75.48	4	9.50	0	"	15.83 "	4.081	1.850 "						
5	0.132	0.688	6378	8017	116.6	5	13.85	0	"	25.1 "	6.650	1.703 "						
6	0.192	0.949	8798	11060	160.9	4	16.95	0	"	31.38 "	8090	1.99 "						
7	0.230	1.199	11115	13814	201.14	5	19.5	0	"	36.32 "	9362	2.15 "						
8	0.289	1.507	13971	17562	255.55	4	21.6	0	"	40.4 "	10415	2.453 "						
9	0.411	2.143	19871	24947	363.2	4	16.95	10,000	15250	1.585×10^{-2}	11,920	3.275 "						
10	0.630	3.285	30445	38257	556.8	5	18.96	"	"	51.28 "	13,220	4.210 "						
11	0.850	4.432	41110	51666	752.16	4	20.3	"	"	57.72 "	14110	5.328 "						
12	1.205	6.284	58255	73222	1065	3	25	"	"	58.15 "	14,990	7.105 "						
13	1.875	9.776	90631	113901	1657	3	22.87	"	"	61.86 "	15,950	10.39 "						

Internal Diameter	19.9	cms
" area	311.026	sq. cms
External Diameter	23.860	cms
" area	447.1	sq. cms
Mean diameter	21.88	cms
Annular area	136.074	sq. cms
Mean circ.	68.74	cms
Mean width	1.958	cms
Mean volume	266.5	c.c.
Mean cross section	3.879	sq. cms
Mean mass	1965.9	gms.
Sp. g. mean	7.377	

Winding: 2 secondary coils of silk covered wire, each having 20 turns, and situated at opposite points on the ring
1 primary coil of 3 layers 1st layer 324 turns
2nd " 322 "
3rd " 281 "
Total 927 .

16 × 20·5 = 328 × 512 = 16800

$$l = \frac{\text{dist}}{pc} = \frac{456.4 \times 10^3}{1035 \times 2\pi 8} = \frac{456.4 \times 10^3}{2 \cdot 142 \times 10^3} = 2.573 \times 10^6 = 2.573\,l.$$

Results of Tests made on the Edison Experimental Alternator at Schenectady May 15th 1891.

The armature is now made up of 0·012" disks separated by sheets of linen paper in the usual way. The field is exactly in the condition described in previous data and tests see book III p 188 and IV 95 + 132. Core of the fields 24·97".

The first test was without load, (one series of 12 amp lamps only) and varying field :– Started at 12h 30

No of obs	Time & Interval	Rev in cent.	Multiplier	Reading	Actual effective	Max Field on Armature Effective	Temp on main coils	Amps Armature	MMF in ampere turns	Inductivity Ingot & Ratio	Reluctance of circuit	Current in field	Speed of dynamo rpm.	Number rpm.	P.D. on field
1	5750	0	1	136·5	136·5	6705 / 7000	273	410	1030	1·144 / 1477700	8·01 ×10 / 8·07	1·5	1230	20·5	
2		500	1·814	66·5	122·4	1723·1 / 1793		410	1030	1·031 / 1486	4·99 / 8·99	"			
3		1500	3·61	72·5	261·7	3717 / 4144		833	2094	2·503 / 2448	8·50 / 8·55	3·05			
4		3500	7·09	56·5	400·6	5550 / 6892		1365	3431	3·323 / 3·7246	18·17 / 9·185	5·			
5		"	"	92	652·4	9024 / 10035		1911	4803	4·527 / 5·1251	8·57 / 7·6870	7·0	1220	20·33	
6		6000	11·444	47	537·7	7468 / 8447		1775	4461	4·327 / 5·030	7·65 / 8·09	6·5			
7		"	"	65·5	749·4	1040 / 1177		2458	6178	5·115 / 7·006	8·61 / 8·62	9			
8		"	"	84	961·2	1335 / 1510		3003	7550	7·032 / 8·986	8·33 / 8·360	11			
9		"	"	101·5	1161	1612 / 1824		3550	8922	8·377 / 10·06	8·43 / 8·32	13			
10		"	"	112·5	1288	2223 / 2513		4096	10300	10·62 / 12·02	9·50 / 8·55	15			905
11									5000		between 7500 and 10000				

12. 00 Stopped for temperature. Res. of armature 1·7 ω at this temp.

·30 Started again. Temp. on armature by thermometer 60°C. air 26°

·30 113·5 114·0

·52 112·5 114·75

16·30 Stopped again for temperature. Resistance of arm: 2·1 ω.

Calculated rise of temp. by res: $\frac{2.1}{1.7} - 1 = 0.2333 = 58.3° = 118.3°$ C. total

·32 Started again.

17·20 Stopped for temp.

·45 Temp of arm: by thermometer 100° C.

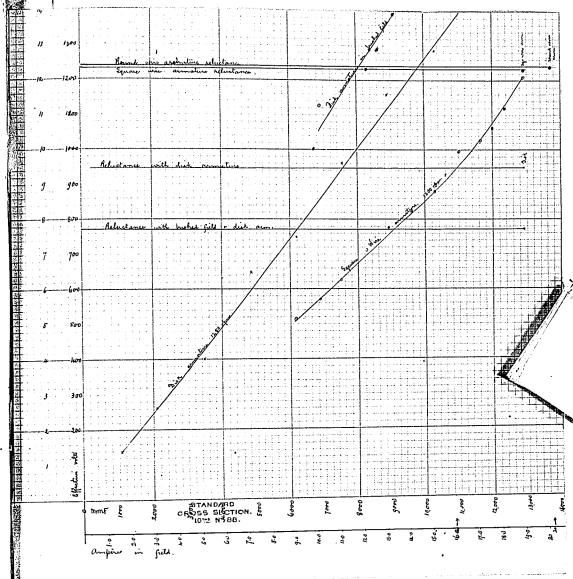
20. 0. Started again, and this time on load. Speed 1130 rpm

No of Obs.	Time	Interval	Rev in Coulomb	Multiplier	Reading	effective Ef.	Current in field	Amps Armature	MMF	Loads current effective	Amps	Rev. of armature	Eff. Amp.	Eff. dist.	L calculated
1	20·0		6000	11·435	114·5	1309	14·75	40·26	10120	–					
2	·15	0·25	"		101·5	1161	14·2	38·77	9750	20·7					
3	·22	0·3	"		101·5	1161	14·2	38·77	9750	21·8	100	2·	43·6	56·4	2·57 L
4	21·00	1·0													

21·00 Stopped for temperature. Res. 1·97 ω Temp. by calculation from this res: 1·165 = 41 + 60 = 101°C. by thermometer 86° C.

Bore 11" × 1·75" × 0·9 = 17·3 sq. ins. effective = 111. 6 sq. cms.

Avg volts 82 sq. cms.


Resist. due exclusively to friction
Resist. due exclusively to friction
Resistance with disk connected
Resistance with brushes field + disk conn.
STANDARD
CROSS SECTION.
10 cm. N°88.

Alternator Tests continued –

16th May 01.

A brushing of wrought iron plate 0·1" 0·25 cm was next inserted in the field covering the whole width of the magnets & the armature was next revolved in this field and voltages observed –

No.	Rev with Ander	Multiplier	Observed reading	Effective Pd	Amps in field	MMF 6864	Speed rev per min 120/10	EMF Harmonic	Time secs	ρ
1	6000	11·1435	88·	1006	9·75	6692	1220 20·3	1423	8.542×10^{-5}	7.833×10^{-7}
2			99	1132	10	6864		1601	9·61 "	7·144 "
3			103	1178	10·5	7210		1666	10·0 "	7·21 "
4			108	1235	12	8236		1746	10·48 "	7·86 "
5			112·5	1288	12·25	8407		1821	10·93 "	7·69 "
6			1285	1390	13·25	9094		1966	11·80 "	7·71 "
7			1213·5	1412	13·5	9265		1997	11·99 "	7·73 "
8			129·5	1481	14·2	9746		2094	12·57 "	7·75 "
9			132·5	1515	14·5	9952		2143	12·88 "	7·73 "
10			133·5	1527	14·7	10090		2159	1296 "	7·78 "
11			112·5	1288	14·5	9952	1210	1821	1093	
12			107·5	1230	12·8	9470	1170	17400		
13			89	1018	11·2	7690	1090	11440		
14			83	949	12	8240	990	13142		
15			98	1121	15	10300	970	1585		

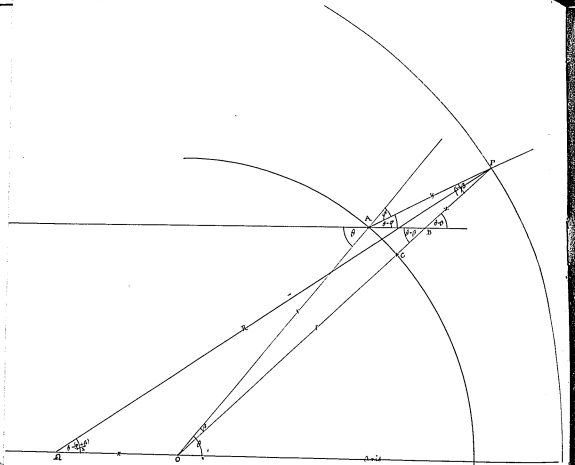
The brushing was now removed and the load applied to the machine – Results as follows – started at 10·0 clock.

No.	Potential Ander	Effective Pd.	EMF Harmonic	Rev with Ander	Multiplier	Amps in field	Effective Load	Rev of min estimate	dampf	oil	Lt	Speed rpm	Speed rps	Energy
	635	736·2 63·	·	6000	11·1435	9	·	20	20			1230	20·5	
2	86	983·4				11·5	·	·	·			·	·	
3	105·5	1206				14·2	·	·	·			·	·	
4	95	1086				12·5	26·5	·	·		·	1230	·	
5	94	1075				13·35	33·7	·	·			·	·	
6	96	1098				13·75	35	·	·			·	·	
7	94	1075				13·44	344	·	18$	68	62 21·C	·	·	36·5 kw

Now stopped for temp.

12·30 Temp on field was 49·C.

" " armature 115·5·C.



Let $O\Omega = x$
$OC = OA = r$
$\Omega P = R$
$CP = z$
$AP = y$

Then $\frac{x}{r+z} = \frac{\sin(\frac{\varphi-\beta}{2})}{\sin(\theta-\frac{\varphi}{2}-\frac{\beta}{2})}$

$\frac{r+z}{r} = \frac{\sin\varphi}{\sin(\varphi-\beta)}$

$\frac{r}{r+z} = \frac{\sin\beta}{\sin\varphi}$

$\therefore \frac{x}{y} = \frac{\sin\varphi}{\sin\beta} \cdot \frac{\sin(\frac{\varphi-\beta}{2})}{\sin(\theta-\frac{\varphi}{2}-\frac{\beta}{2})}$

This is the required relation between x and y in order that O may be the focus. But whether O is a focus or not $\frac{y}{r} = \frac{\sin\beta}{\sin(\frac{\varphi-\beta}{2})}$

$\therefore \frac{x}{r} = \frac{\sin\varphi}{\sin\beta} \cdot \frac{\sin(\frac{\varphi-\beta}{2})}{\sin(\theta-\frac{\varphi}{2}-\frac{\beta}{2})} \cdot \frac{\sin\beta}{\sin(\frac{\varphi-\beta}{2})}$

$= \frac{\sin\varphi}{\sin(\theta-\frac{\varphi}{2}-\frac{\beta}{2}) \pm \cos(\frac{\varphi-\beta}{2})}$ where $\sin\varphi = \frac{1}{\mu}\sin\theta$

From this equation determine β in terms of θ, x, and r in order that $\frac{x}{r}$ may be independent of θ

$\therefore \frac{\sin\theta}{\mu}$ / $\frac{1}{2}\{\sin(\theta-\beta) + \sin(\theta-\varphi)\} = \frac{1}{r}$

" $\frac{\sin(\theta-\beta)+\sin(\theta-\varphi)}{\sin\theta} = \frac{1}{\mu x}$

(153)

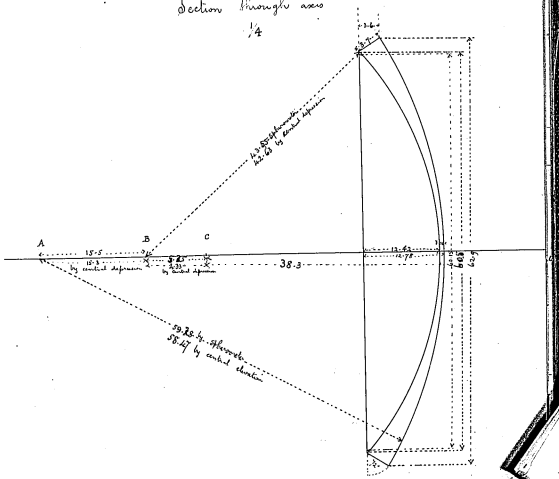
Determination of the geometrical relations in a Mangin reflector

A concavo-convex lens of glass of refractive index μ is generated by two excentric hemispheres of radii r and R. It is required to find what shall be the lengths R and x in order to converge a beam parallel to the axis to a focus at the origin O of r on the axis.

This was the problem as stated by Mr Dobbie. It appears however from the equations at the foot of the opposite page, in which the right hand side is a constant, that no value of β except $\mu = 1 + \beta = \varphi$ will satisfy it. The problem has therefore to be stated afresh under new conditions.

The following are the dimensions of a glass reflector of this kind silvered on the convex surface, and made by Mess. Sautter-Lemonnier.

Section through axis
¼



A is the centre of the external and silvered surface
B . . . . internal - unsilvered -
C . . . principal focus

The curvatures appear to be uniform on both faces of the lens.
The external spherometer reading is 4·902
. . internal . . . 5·809
. . zero . . . 5·332

From 38·3 from the mirror surface. Weight 30lbs.

Reflector Data continued :— In the opposite figure

Let AB be an incident ray parallel to the axis OV. Let it be refracted at incidence along BC, back from C by simple reflection along CD and then refracted to F the principal effective focus of this combination. Let R be the radius of the inner and silvered circle

" " " " " " mirror " unsilvered.

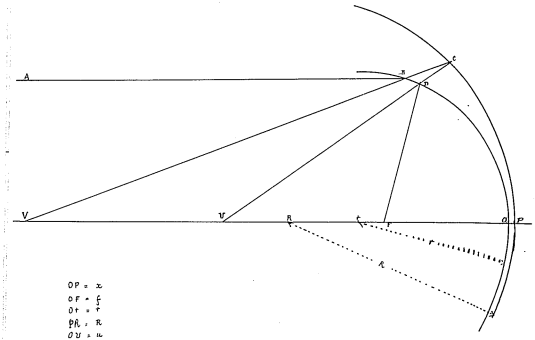
OF = f be the focal length for parallel rays

OV = v " " equivalent focus of the mirror

OV = v " " " " " of the refracted beam

on entering).

μ = the refractive index of the glass with air for the species of light considered.



OP = x
OF = f
Or = t
PR = R
OV = u
OV = v

The strict formulae are :—

$$\frac{1}{v} = \frac{\mu-1}{\mu}\cdot\frac{1}{r} \qquad (1)$$

$$\frac{1}{v+x} + \frac{1}{u+x} = \frac{2}{R} \qquad (2)$$

$$\frac{\mu}{f} - \frac{1}{u} = \frac{\mu-1}{r} \qquad (3)$$

Since x is a small quantity by comparison, let us write

$$v+x = mv$$
$$u+x = nu$$

Equation (2) then becomes

$$\frac{1}{mv} + \frac{1}{nu} = \frac{2}{R}$$

$$\therefore \frac{1}{v} = \frac{2n}{R} - \frac{n}{m}\cdot\frac{1}{v}$$

$$\therefore \frac{\mu}{f} = \frac{\mu-1}{r} + \frac{2n}{R} - \frac{n}{m}\cdot\frac{\mu-1}{\mu}\cdot\frac{1}{r}$$

$$= \frac{\mu-1}{\mu}\cdot\frac{1}{r} + \frac{2n}{R} - \frac{n}{m}\cdot\frac{\mu-1}{\mu}\cdot\frac{1}{r}$$

$$\frac{1}{f} = \frac{\mu-1}{\mu}\cdot\frac{1}{r} + \frac{2n}{\mu R} - \frac{n}{m}\cdot\frac{\mu-1}{\mu^2}\cdot\frac{1}{r}$$

$$\frac{1}{f} = \frac{m\mu R(\mu-1) + 2mn r\mu^2 - nR(\mu-1)}{mR\mu^2 r}$$

$$f = \frac{m\mu^2 Rr}{2\mu mr + R(\mu-1)(m\mu - n)} \qquad (4)$$

And $\frac{1}{\mu^2} + \frac{1}{\mu}\left(\frac{2n}{R} - \frac{n-n}{n}\right) = n\left(\frac{v^2-f}{f^2 v^2}\right)$

or $\frac{1}{\mu^2} - \frac{2}{\mu}\left(\frac{m+n}{2m} - \frac{2}{R}\right) = n\left(\frac{v^2-f}{f^2 v^2}\right)$

$$\frac{1}{\mu} = \frac{m+n}{2m} - \frac{n}{R} \pm \sqrt{n\left(\frac{v^2-f}{f^2 v^2}\right) + \left(\frac{m+n}{2m} - \frac{1}{R}\right)^2} \qquad (5)$$

In the case of the mirror examined R = 58·47 r = 42·63 f = 38·3

from these μ = 1·522.

It is to be observed however that these formulae assume the two circles to coincide at O.

Taking the more accurate formulae.

$$\frac{r}{f} = \frac{\mu-1}{\mu} + \frac{2m}{\mu}\frac{r}{R} - \frac{n}{m}\frac{\mu-1}{\mu^2}$$

If r/f = 1 this requires

$$\frac{2n}{\mu}\frac{r}{R} = 1 - \frac{\mu-1}{\mu}\left(1 - \frac{n}{m}\frac{1}{\mu}\right)$$

$$\frac{n}{R} = \frac{\mu}{2} - \frac{\mu-1}{2}\left(1 - \frac{n}{m}\frac{1}{\mu}\right)$$

$$\frac{r+x}{R} = \frac{\mu}{2} - \frac{\mu-1}{2}\left(1 - \frac{n}{m}\frac{1}{\mu}\right) \qquad (6)$$

It is best to treat $\frac{n}{m} = 1$ at first and then ascertain the correction

If $\mu = 1{\cdot}5$ $\quad \frac{r+x}{R} = \frac{3}{4} - \frac{1}{\mu}\left(1 - \frac{2}{3}\right)$

$$= \frac{9}{12} - \frac{1}{12}$$

$$= \frac{8}{12} = \frac{2}{3}$$

Test of the Lieb Motor before rewinding it for Battery and Fan work.

Analysis of operation on 110 volt circuit
Turns on armature · 29 × 22 = 638. Wire all round 12⅞ × 2?
The following observations were made with the machine operated as a shunt dynamo :-

No. of Obs.	Amps in Stn leads	Field amps	Speed r.p.m.	MMF	Speed. Rpm.	Rps.	Volts at mt. terminal	Φ Flux/cm²	Φ in gauss/sq. inch	3φ	ρ			
1	0.3660	0.2741	426	536	3980	66.33	15.5	1881 X10	740	2.92 X10⁻⁸				
2	1.130	0.851	1323	1663	"	"	24.4	3475 "	1405	4.78 X10⁻⁸	2.85 X10⁻⁷			
3	1.2915	0.9724	1511	1899	"	"	27.6	4.018 "	1623	4.732 "	2.34 X10⁻⁷			
4	0.9839	0.2971	1149	5644	"	"	11.84	1.398 "	565.8	4.935 "	2.02 X10⁻⁷			
5	0.1853	0.1395	217	273	"	"	7.90	0.933 "	377.3	2.925 "	1.86 X10⁻⁷			
6	1.6614 0.395	1.253 1.33	1947	2447	"	"	40.88	4.828 "	1953	5.07 "	3.54 X10⁻⁷			
7					"	"								

Polar area 4.0 × 6 = 24 sq cms. Pole face 5.15 − 4.3 = 0.85 = 0.425
Reluctance $4.25 \times 10^{-4}/24 = 1.75 \times 10^{-5}$

Wound the armature with 1½ # 19 B&S. wire 0.0422" cond. ½ 0. " in each section = 15½ wires all round. 10 feet in each section = 110 ft. 27.5 feet equivalent res. = $5.85 \times 2.75 \times 10^{-2} = 0.16$ ω cond. say 0.2 ω warm between brushes.

$0.001617\ (1 + 20 \times 0.00021) = 0.001617\ (1 + 0.0042) = 0.0016238\ \omega$ @ 21°C.

$2722.25 + 6170 = 8892.25$

$\frac{2722.3}{8892.3} \times 0.0016238 = 0.0004971\ \omega$ @ 21° C.

$2722.25 + 1730 = 4452.25$

$\frac{2722.3}{4452.3} \times 0.0016238 = 0.0009929283\ \omega$ @ 21°C.

$2722.25 + 2729 = 5451.3$

$\frac{5451.3}{2722.3} = 2.0023$

$\frac{99283}{49710} = 1.9974$

(58)

Test of Standard resistances for the measurement of currents on Underground Feeders.

For the design of these resistances see p. 136.

There are two instruments one with 6 strips, the other with 12.

The strips are 30.35 long, 7.62 broad and 0.0203 thick.

The convective surface per strip is 231.3 sq. cms. $\times 2 = 462.6$

" " for the 6 strip res; is 2775 sq. cms.

" " " " 12 " " $= 5550$ " "

Measurement of the resistance by comparison with the large shunt on the 23rd May 91.

46 ω added to right hand coil of H+B. galvo: for equality.

This included, the resistance = 5442.50 T.B. 21.2° C.

Comparison of 12-plate grid, battery and large shunt

6170 ω added to shunt Res; @ 21° C. 0.0004971 ω } Corrections see p. 163

Comparison of 6-plate grid and large shunt:-

1730 ω " " shunt. Res; @ 21° C. 0.0009928 ω }

Comparison of 6-plate + 12plate grid.

2729 ω added to 6 plate. Ratio = 2.0023. Ratio of above results = 1.9974

For ordinary purposes the resistances may be treated as 0.001ω + 0.0005ω respectively.

The following temperature elevations were observed with these resistances

Obs.	Current	Drop.	Energy Watts	Energy per sq. cm.	Energy per cubic cm.	Energy per sq. cm.	Temp.	Elevation	Emission log. °C. Newton				
I. 1.	470	0.07	32.9	0.8187	0.02691	0.001511	23.0	2°	0.0017 18				
II.	70	0.035	2.45	0.2042	0.007529	0.000113	23.0	2°	0.00044				
V. 2.	95	0.095	9.025	1.502	0.049476	0.006706	29	7	0.00093				
IV.		0.0475	2.578	0376	0.012379	0.000646	27	6	0.00066				
V. 3	180	0.180	32.4	5.4	0.1779	0.02335	40.5	19.5	0.00117				
IV.		0.090	16.2	1.85	0.060948	0.00829	29.5	16.7	0.0003				
VI. 4.	200	0.200	40.0	6.6	0.2175	0.02855	47°	26°	0.0011				
VI.		0.100	20.0	1.65	0.054336	0.007134	38.8	17.8°	0.00014				
VI. 5	220	0.110	24.2	2.065	0.0680	0.008930	48°	27°	0.0003				
VI.			24.2		0.0680								
VI. 6	310	0.155	48.05	4.6	0.1515	0.0173	55°C	37°	0.0005				
VI.			48.05		0.1515								
VI. 7	370	0.185	68.45	7.2	0.1878	0.02465	71°C.	50°	0.00069				
VI.			68.45		0.1878								

Test of a cell brought by Mr Hamilton from Messrs Burnell & Co.

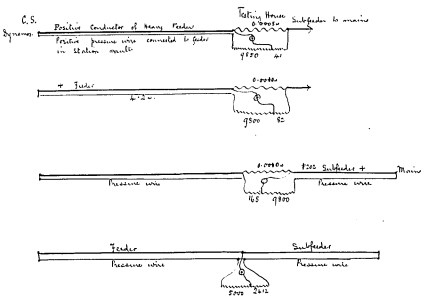
26th May 91.

Cell is contained in a 3p. case rectangular. It is sealed at the top with paraffine wax through which project two binding posts and a vent tube. The case is stamped Kilo compound

EMF 2.46 volts Int. res: 0.04 ω.

The cell gives on short circuit a current sufficient to melt a #19 B.W.G. copper wire.

On opening it was found to be a secondary cell using zinc and peroxide of lead as elements. H₂SO₄ solution.



Measurement of the resistances of Brooklyn Feeders 24th May.

The two standard resistances whose tests are recorded on the preceding page were used in these measurements. The connections adopted were those on the opposite page. The long feeder is #1000 and has a length of 9260'. The shorter subfeeder is #500 and is 2250 long. Let r_1 be the resistance of the 0.001 strip r_2 to be the resistance of #1000 The pressure wires are stranded of seven #15 B.&S. wire 0.057" having each a resistance each of 0.003167 ω per foot, or a joint resistance of 4.524×10^{-3} ohms per foot. in 9260' ω res: of 41.19 ω

The resistance of the long + conductor in the feeder by the 1st test

$= \frac{9854}{41} r_2 = 240.37\, r_2$ at temp. of about 20° C.

The resistance of the same conductor by the 2nd test.

$= \frac{9804}{82} r_1 = 119.56 r_1$ at same temperature.

The resistance of the subfeeder by the 3rd test

$= \frac{9802}{165} r_1 = 59.402\, r_1$ at same temperature

The ratio of feeder to subfeeder by these 2nd + 3rd tests = 2.013

The ratio . . . . . the 4th test $= \frac{5000}{2414} = 2.079$

The res: per foot of #1000 feeder @ 20° C should be 1.0325×10^{-5} ω

" " " " #500 " " " " 2.065×10^{-5} ω

The pressure wire of the long feeder was connected with the feeder positive in the station vaults. That of the subfeeder by copper wire in the junction box with the mains.

The galvanometer was a Thomson minor galvanometer used at first with $\frac{1}{100}$th shunt, and finally unshunted.

The ratio of the two feeder resistances should be $\frac{9260}{2480} = 2.057$

With $r_1 = 0.000993$ the feeder = ~~0.00187~~ ω or 1.282×10^{-5} ω per foot 24.3% high
- subfeeder = 0.05898 ω . 2.638×10^{-5} ω . . 27.7% .

With $r_1 = 0.000\,8523$ the feeder = 0.1019 ω = 1.100×10^{-5} ω per foot 6.6% high
- subfeeder = 0.05064 ω . 2.261×10^{-5} . . . 9.5% .

Speed and pressure of the Lamp: Room Dynamo #10 started 3rd June 91

The belt on the newly set up #10 dynamo is operated by a new 60" pulley. The belt is 37 feet long and makes 1334.5 passages per minute or 4980' per min. The pulley of the #10 is 13" diam 3.1404' circ. = 1463 r.p.m. At this speed the machine generates 150 amp: with 1140.5 volts upstairs and 1144 volts at terminal, with about ⅛ of the resistance box left.

1.00028 @ 16.9 is my standard

1.00028 × 1.00088 = 1.00116.

17.9 − 15.5 = 2.4 × 3 = 7.2

1.00072

$\frac{2707}{2687} = 96.44$ ∴ 2706.8 + 71 : 999644 × 28.07 :: x : 1.0006

2777.8 : 28.060 :: x : 1.0006

$\frac{2687}{100} = 28.07$ $x = \frac{1.0006 \times 2777.8}{280.600} = 0.0099002$

2706.8 + 1100 = 3806.8

$\frac{5.4135}{1504.8} = 1.1502$ 2706.8 : 9311 × 1.8732 :: x : 1.0006

$\frac{7.4136}{5806} = 1.311$ $x = \frac{1.0006 \times 2706.8}{9311 \times 2.9934} = \frac{1.0006 \times 2706.8}{27844}$

$\frac{2706.8 + 3100}{2000} = \frac{5806.8}{2000} = 2.9034$ = 0.10017

2706.8 + 3315 = 6021.8

$\frac{18065.4}{9021.5} = 2.0032$ 2706.8 : 9002.2 × 3.00727 :: x : 1.0040

$\frac{2706.8 + 6315}{3000} = \frac{9021.8}{3000} = 3.00727$ $x = \frac{1.0040 \times 2706.8}{9002.2 \times 3.00727} = \frac{1.0040 \times 2706.8}{27070} = 0.10040$

2706.8 + 80 = 2786.8

$\frac{2706.8 \times 1500}{4285.8} = \frac{4159.9}{4285.8} = 1775.15$ 2706.8 : 9475.1 × 2.8579 :: x : 1.001

$\frac{2706.8 + 1500}{1500} = \frac{4286.8}{1500} = 2.8579$ $x = \frac{1.001 \times 2706.8}{9475.1 \times 2.8579} = \frac{1.001 \times 2706.8}{27079} = 0.10001$

$\frac{27065}{3706.5} = 730.8$ 2706.8 + 995 : 9730.8 × 3.7065 :: x : 1.001

$\frac{2706.8 + 1000}{1000} = 3.7068$ $x = \frac{3601.8 \times 1.001}{3.7065.8 \times 9730.8} = \frac{3606.54}{36087} = 0.09996$

19 − 17 = 2 × 0.03 = 0.06

2706.8 / 1500 : 9817.5 × 4.3835 :: x : 1.001

$\frac{21654}{3506.5} = 617.5$ $x = \frac{1296.8 \times 1.001}{4.3835 \times 9817.5} = \frac{4301}{43035} = 0.09994$

$\frac{3506.5}{800} = 4.3835$

2706.8 + 195 = 2901.8 2707 : 9489 × 2.9345 :: x : 1.000035

$\frac{1500 \times 2901.8}{4401.8} = \frac{4352.7}{4401.8} = 989$ $x = \frac{2707 \times 100035}{9489 \times 29345} = \frac{27079}{278455} = 0.0097247$

$\frac{2901.8 + 1500}{1500} = \frac{4401.8}{1500} = 2.9345$

0.8 0.0098

$\frac{2707 \times 1000}{3707} = 730.$ 2707 : 9730 × 3.707 :: x : 1.00009

$\frac{2707 + 1000}{1000} = 3.707$ $x = \frac{0.10009 \times 3729}{9730 \times 3707} = \frac{3732.09}{36069.1} = 0.0095183$

4087 + 2707 = 6794 $\frac{2707}{6794} \times 0.02462 = 0.009796$

4090 + 2707 = 6797 $\frac{2707}{6797} \times 0.0245 = 0.009756$

$\frac{2707 \times 1000}{4707} = \frac{5407}{4707} = 1.1485$ 2707 / 7194 : 9118.5 × 2.3535 :: x : 0.0098

$\frac{4707}{2000} = 2.3535$ $x = \frac{3626 \times 0.0098}{9118.5 \times 2.3535} = \frac{35532}{21453} = 0.0016561$

$\frac{2707 \times 1500}{4207} = \frac{40605}{4207} = 965.2$ 2707 / 7194 : 9465 × 2.8047 :: x : 0.0098

$\frac{4207}{1500} = 2.8047$ $x = \frac{4426 \times 0.0098}{9465 \times 2.8047} = \frac{43375}{265465} = 0.001634$

Comparison of Standard Resistances 25th May.

(160)

Differential Galvo. H.B. with 1.5w added to rt.-hand coil.
Res: of both coils 514.13.5w 100ºfires 19°C T.P. = 2706.75w each coil.

1st Test comparison of two standard ohms coils @ 17.9°C. in watts.
1w added to my standard, a ratio of $\frac{2709.75}{2706.75} = 1.00044$ it should be 1.0

2nd Test. Comparison of 1/10th Coil, with new Std. 1w
7½ added to 1/10th, reduction 9900 : 100
Res: of 1/10th w @ 18°C. 0.009996 w.

3rd Test. Comparison of 1/10th Coil with new Std. 1w.
Bridge reduction 8000 : 2000, and 1180w inserted
Res: of 1/10th w @ 18°C. 0.10017w. = 1.0019 @ 19°C.

4th Test. Repetition of above
Bridge reduction 7000 : 3000, and 3315w inserted

Res: of 1/10th w @ 18°C. 0.10010w. = 1.0012 @ 19°C.

5th Test. Repetition of above Temp. of Std. 19°C.
" Bridge reduction 8500 : 1500 + 80w inserted

Res: of 1/10th w @ 18°C. 0.10007w. = 1.0009 @ 19°C.

6th Test. Repetition of above. Temp. of Std. 19°C.
Bridge reduction 9000 : 1000 + 895w added to 1/10th

Res: of 1/10th w @ 19°C. 0.09988w.

7th Test Repetition of above. Temp of Std: 19°C.
Bridge reduction 9200 : 800 + 1590w added to 1/10th

Res: of 1/10th w @ 19°C. 0.09994w.
Mean of all 5 tests ~~0.09999~~ 0.1000032 @ 19°C. = correct @ 17.5°C.

The ratio of the legal to the true ohm is $\frac{1000}{1063} = 0.99625$ reciprocal 1.0028
a change of 19.3°C. so that their resistance is correct at its true ohm at 30.8°C.

8th Test Comparison of 1/10th with 1/10th @ 19.3°C.
Bridge reduction 8500 : 1500 + 195w added.

Res: of 1/10th w @ 19°C. = 0.09972

9th Test Comparison of 1/100th with 1/10th @ 19°C. 1/10th 20.5°C.
Bridge reduction 9000 : 1000. 722w added to 1/10th

Res: of 1/10th @ 19°C. = 0.09952

10th Comparison of upper shown grid with 0.01w std. 23.6°C.
4087w added to upper grid which by account is 0.02462.
~~4087~~ Res: of 1/10th @ 20.6°C. = 0.009996.
4090w added to lower grid which is 0.0245 by account
~~4090~~ Res: of 1/10th @ 20°C. = 0.009756 w.

11th Comparison of large shunt against 1/10th w.
Bridge reduction 8000 : 2000 + 919w added to grid

Res: of large grid 0.001650 @ 20°C.

12th Repetition of above Bridge reduction 8500 : 1500
+ 1719w added to grid.

Res: of large grid 0.001634 @ 20°C.

2[illegible] 15[illegible]

J. C. Henderson Esq.

Engineer-in-Ch[illegible]

Edison General [illegible] Co.

New York.

Dear Sir :-

I beg to report as follows upon the sample of silicon bronze trolley wire, received here on the 22nd. inst., and accompanying your letter of that date

Gauge # 4 B&S, Mean diameter 0.2589"

Specific gravity 8.88

Weight per foot 0.1727 lb. per mile 911 lbs.

Conductivity 22.8 % of Matthiessen's standard hard drawn copper at temperature of test (20 °C.)

Resistance per foot at 20°C. 0.00024 ohm, per mile 1.38 ohms.

Tensile strength 4200 lbs. (eight (no appreciable extension by any stress under 1000 lbs.), or 71,100 lbs. per sq. in.

Ductility 50 twists in twelve inches.

Full particulars of tests can be given on demand.

Yours faithfully,

[illegible]

Consulting Electrician.

Test of a sample of Trolley-Wire (Silicon Bronze) received from the Engineering Department on the 22nd May 91.

The diameter was measured by micrometer as follows.

1	0·2396	
2	0·2403	
3	0·2394	
4	0·2394	
5	0·2395	
6	0·2394	
7	0·2395	
8	0·2395	
9	0·2395	
10	0·2395	
11	0·2391	
12	0·2394	
13	0·2396	
14	0·2398	
15	0·2397	
16	0·2396	
17	0·2397	
18	0·2398	

Means	Means	Area	Area	Weight
"	ems.	sq ems	sq. ins	per cu.
0·2396	0·6086	0·29092	0·045109	2·569 gm

Weight		Lbs weight	
per foot	per mile	per foot	per mile
78·3	413400	0·1727	911·4

The distances was measured along the wire as follows:-

1st Measurment	2nd Measurment	Means.					
654·6	654·7	654·65					
1085·1	1085·2	1085·15					
1690·6	1690·8	1690·7					

Comparison of Res resistances of three lengths with the 0·01 m. Std.

Length	Res. of Gds	Std. Res.	Res. ratios	b	Ratio	Res. of length	Res. per 1 mm	Resistivity of length in C.G.S. units	20°C. Standard Matthiessen Resistivity	% conductivity
654·6 (Mean 7	2707	0·0098	6819	Volley	9·526	0·032409	7·402 x10⁻⁵	6·115 x 10⁻⁶	1761	28·8
1085·15	"	"	3592	-	9·299	0·022805	2·101 -	6·112 x 10⁻⁶	Mean drawn 1634·00·	28·8
1690·6	"	"	1156	-	3·813	0·013902	2·109 -	6·135 x 10⁻⁶		28·8

Comparison with a standard copper bar

Length of bar between reading marks	Area	Equivalent length of trolley wire	Equivalent length of rod 0·2396	% cond. by strength	Equivalent length of hard rod at 0·2396	% Cond. hard rod		Res. per ft	Res. per mile	
728	0·2267	71·5	243·8	29·3	238·4	29·99		0·0006600	3·381 Ω	

Test for sp. g. Two samples cut off about 5 cms long

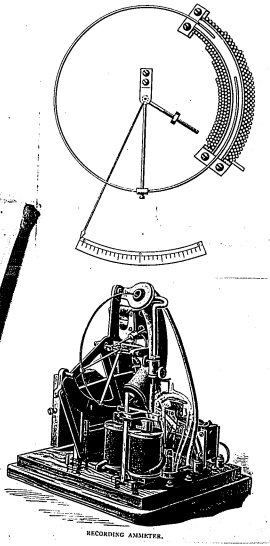
No 1.	in air	14·40445	No 2.	in air	14·05·85
	H₂O	12·7992		H₂O	12·4885
	loss	1·6125		Loss	1·57305
	Sp. g.	8·93		Sp. g.	8·932.

Breaking stress by spring dynamometer

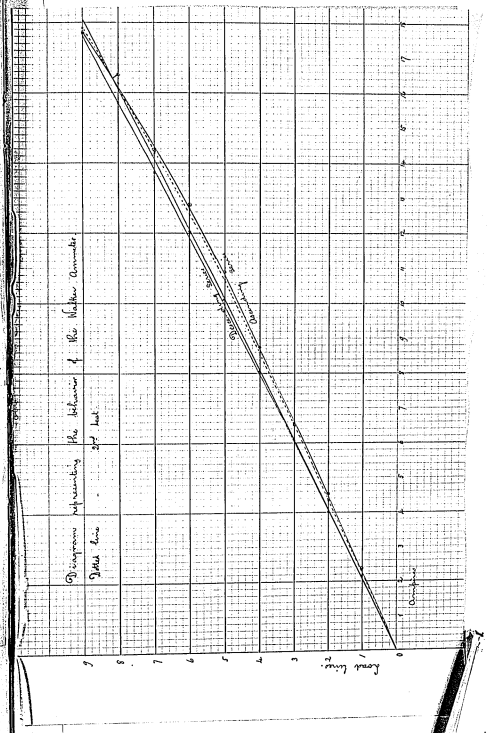
1st length 3000 lbs
2nd - 3220 -
Mean - - - 3125 lbs.

69,200 lbs. per sq.in., taking 3200 lbs. 70,060 lbs. per sq. in.

Three tests for ductility gave #1, #2 bents in 12" The last is perhaps the #2, #7 - - - most reliable.
#3, #0 - - -



RECORDING AMMETER.



Determination of a 500-volt winding for the 1 HP. new Edison Motor 27th May 91.

ed to be 1800 revs. per min at normal flux and light load.
×35 = 140 turns of wire in each groove. The diameter, covered of the
ument wire is 0.061". The covered diameter of the 500-volt wire and
(uniform only) be 0.0305"; with 0.018" for covering this is 0.0823" = #25 B&S.
e wire required is #23 B&S 0.025" cond. 0.037" cov'd. 8 of these = 0.296":
10.03 × 0.296": wide, 17 high = 0.62g"
90 wire with each 0.020" cond. & 0.031" and 14 wire deep = 0.434"

40 turns of #25 B&S wire 0.020" cond. & 0.030" d.c.c. were wound in a
a sample brass block and found to have a resistance of 2.05 = 0.051Ω

Test of Walker Meter Scale 28th May 91.

The arrangements of this photographic registering ammeter are shewn in the accompanying cuts. To ascertain the degree of accuracy of its indications, a telescope was mounted facing the shutters and about 250 cms away from it. By bringing the cross wire vertical, and then opposite each dead hole in the shutter, the current through the instrument was adjusted until the registering slit was bisected by the same cross wire. The following were the readings obtained which seem to shew ~~permanent~~ reciprocal effect of friction between ascent and descent.

Ascension						Descension					
Shade Deflection	Multiplier	Deflection	Amp'rs	Amp'rs per hole	Δ amp	No. of Scale hole	Shade	Multiplier	Deflection	Amp'rs	Amp'rs per hole	Δ amp
0.232	2	0.466	2.394	2.394	2.394	1	0.210	2	0.420	2.167	2.167	2.167
0.440		0.880	4.5761	2.721	2.147	2	0.388		0.776	4.003	2.002	1.836
0.633		1.266	6.532	2.177	1.991	3	0.590		1.180	6.089	2.030	2.086
0.850		1.700	8.772	2.193	2.240	4	0.780		1.560	8.050	2.013	1.961
1.055		2.110	10.885	2.177	2.113	5	0.978		1.956	10.095	2.019	2.045
1.248		2.496	12.80	2.133	1.915	6	1.160		2.320	11.970	1.962	1.875
1.393		2.786	14.38	2.054	1.580	7	1.320		2.660	13.725	1.961	1.755
1.595		3.190	16.46	2.058	2.08	8	1.520		3.040	15.690	1.961	1.965
1.720		3.440	17.75	1.972	1.29	9	1.720		3.440	17.75	1.972	2.060

The angular range of the pointer is 38°. 12'

Calibration of Otoch Galvanometer after remounting
28th May 91.

The silk fiber having broken, a new one was attached, and about ½ of the brass weight filed off the suspension bar, to reduce the weight on the new fiber. The galvanometer was then adjusted and calibrated by electrolysis as follows:—

Time	Mean Chronic reading	Number of Rubbings	Highest Current	Weight before	Joint's sum	Weight after	Joint's sum	Gain	Loss	Mean Weight	Transfer per second	Ampère	Time per ampère
											3.86510"		
6601	+ 0.318	42	0.321	33.9217	75.667	34.2775	75.66	0.3558	0.3560	0.3559	5.9319×10⁻⁵	1.6405	0.1938
			0.315	41.7135		41.3575							
				75.6352		75.635							

The area on one side of each plate exposed to the deposit was about 75 sq. cms. allowing about 50 sq. cms. per ampère.

Test of Standard Resistances in terms of ½₀th ohm Copy

29th May

Looped 70 feet of Boanton Trolley wire along the floor and measured its resistance between fine marks as follows:—

Res: of galvt. d.b. H&B. differential with 5 ω added to alt: limb & coil 5316 ω @ 17°.C. 100/from = 2658 ω per coil.

½₀th ω @ 19°.C. 6220 ω added to 0.1 ω.

Resistances of trolley wire 0.029962 @ 19°.C. 2670.5 cms = 1.44471×10^{-5} ω per cm. Also see pages 128 + 129.

Trolley wire against Bm 01 ω std. 5440 ω added to Trolley wire

Resistance of standard 0.01 ω = 0.009985 ω @ 18°.C. Platinoid
0.009835 Legal ω @ 0°.C.
Comet Legal ω @ 90°.C.

Check— 675.7 cms. equal to the std 0.01 ω = 0.009778 ω @ 18°.C. Platinoid
0.009742 Legal ω @ 0°.C

Large shunt = 112.5 cms. of trolley wire = 0.001628 ω @ 18°.C. = 0.001622 ω @

6 step shunt = 58.9 " " " " = 0.000852 3 ω @ 18°.C. = 0.000848 ω @

12 " " = 29.5 " " " " = 0.000426 9 ω @ 18°.C. = 0.000423 3 ω @

The best values of the Standards are therefore :—

0.1 ω. Test on preparation " correct 0.1 Legal ohm @ 14.°C. 28th Jany 89 p. 78 Book II
" " 18th June 89 " " @ 14.°C. " 125 " II
Platinoid " " 25th May 91 " " @ 17.5°C. most reliable. 149 III

0.01 ω. Mean value before the 20th May 90. 0.009781 @ 0°C see p. 143 Book III
Platinoid Present " " 0.009742 @ 0°C above. 163 " III

0.0016 ω Large grate Measurements 18. III. 89. p. 135 . I. 0.001627 @ 23.6°C. Ht 3 = 0.001619 @ 0°C.
21. X. 90 " 144 . II. 0.001620 @ 22°C - 3 = 0.001613
" " " " 0.001626 @ 25.5°C - 1 = 0.001626
Platinoid 0.021 ƒ. 28th V 91 " 163 " III 0.001628 @ 18°C - 5 = 0.001622
(13) Weighted mean = 0.001619

0.001 6 plate grid as given above on this page 0.000852 3 @ 18°C = 0.000848 800 @ 0°C

0.0005 12 " " " " " " " " 0.000426 9 @ 18°C = 0.000423 300 @ 0°C

6220
1.4
2658 / 8879.5 :: 2659 / 2659.4 :: 0.1000032 : x
x = 0.029962

5440
2665
2668 / 0.4 :: 1.4 / 8106.2 :: as x : 0.029962 x = 0.007855 ω

Data concerning new Edison Electrolytic Meter
29th May 91.

For original electrical design see p. 131.
For following are dimensions after completion.

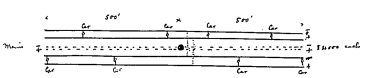
Outer glass cell 11·6 ext: 11·1 int: drain: 17·25 high.
External zinc cylinder 18·35 ext: high 9·1 ext: 8·5 int: diameter. 900 gms
Internal " " 14·35 " " 6·2 " " 6·3 " " 120 "
Thickness of outer cylinder wall 0·118". } Dist ance between 1·1
" inner " " 0·025". }

Density of solution 1·11. Both cylinders amalgamated
Res: of cell 17th May 0·215 ω @ 13°C.
" " 29th " 0·250 ω " " 0·318 ω @ 15·5°C on the 25th May.
Res: of spool 9·6466 ω @ 18·8°. 7·53 ω of 9·3. @ 46°C. } 2·0 ω @ 24°C copper.
2·13 @ 16°C.
This arrangement on 0·4 volt should give a deposit of 5 mgms per ampere hour.

On the cost of copper for a Low-Tension City Street Car system employing a maximum of 20 and a minimum of 15 volts across the mains of the track.

Data Double track, all the conductivity afforded by copper mains. Cars 250 feet apart on each track. Transformers 1000 feet apart. Each car 20,000 lbs. running at 6 mph. up a 3% grade.

Assuming 2 main conductors, and cars at every 125 feet, each transformer feeds four cars up to 500 feet of distance. Gravity = 600 lbs and friction = 15 lbs per ton = 150 lbs. Total 750 lbs. 6 mph. = 22 x 6/15 = 8·8 ft per sec. = 6600 ft lbs per sec. = 12 HP. exerted @ 60% gross efficiency = 20 HP. absorbed = 15000 watts = 1000 amperes at 15 volts or 900 amps. on 17·5 volts the mean pressure.
Load on transformer 3600 amps on each side, carried 250' = 900,000 lbs for 5 volts or 2·5 volts in each main = 360,000 conductivity = 1/10 000 copper: or 4 rods each # 1000, 8 of such rods in all.
Cost per foot $ 5.50 of one main = $11 for the roadway = $58,000 per mile say $65,000 per mile with the plus cost of laying. Probably $75,000 per mile laid.
Each transformer would develop 7200 x 20 = 144 KW. at full load.



Res. of strip in lt. Rd. arm 0·09993 Ω 23°C.

" " eford " " " 99.71Ω + 2·5 = 102·21 = 102·25 with shunt

Ratio $\frac{S}{S+S} = 0.0009702$ = 9.702×10^{-4}

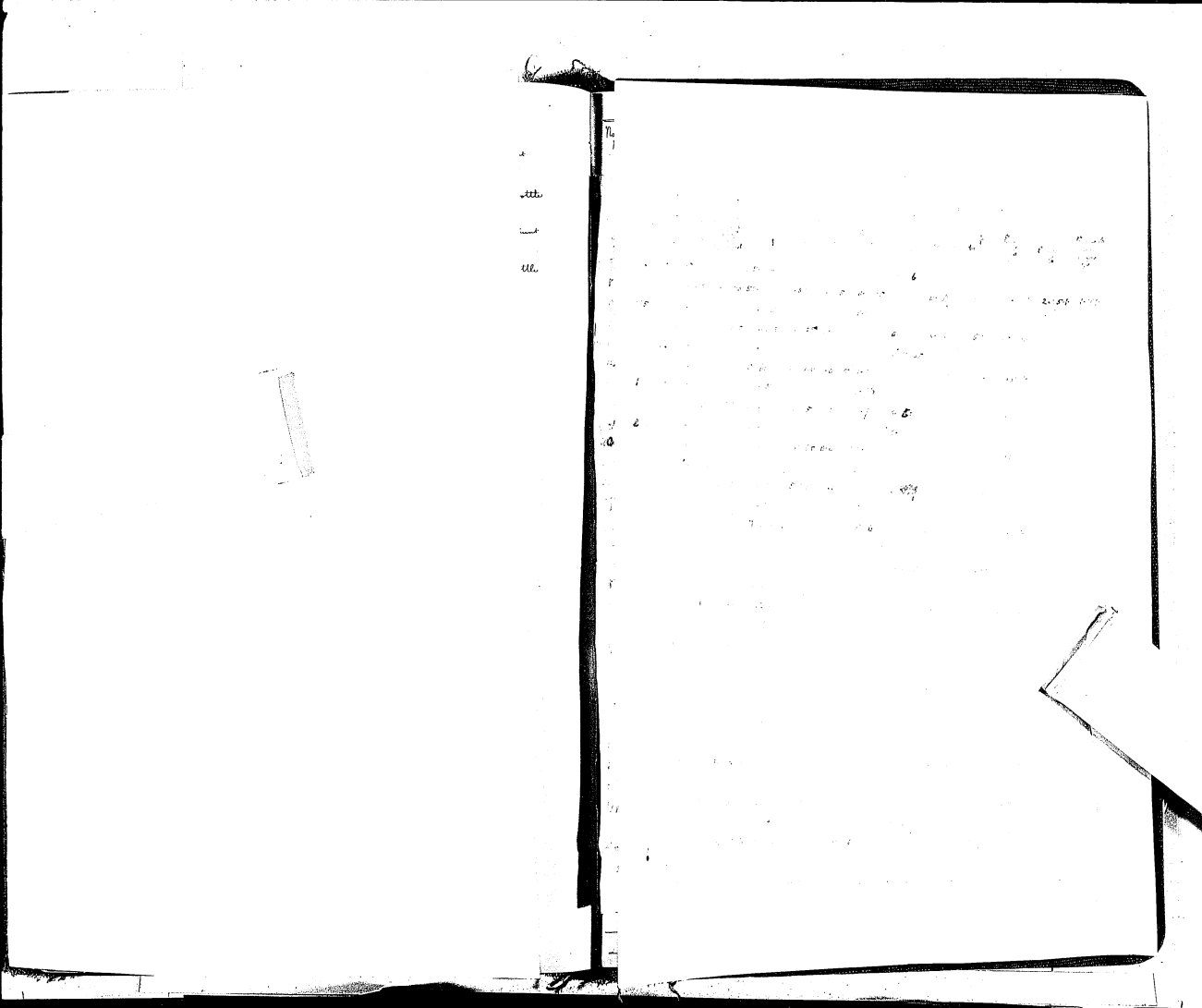
For 1224 mgms transferred in the main circuit 1.18 mgms in the bottle

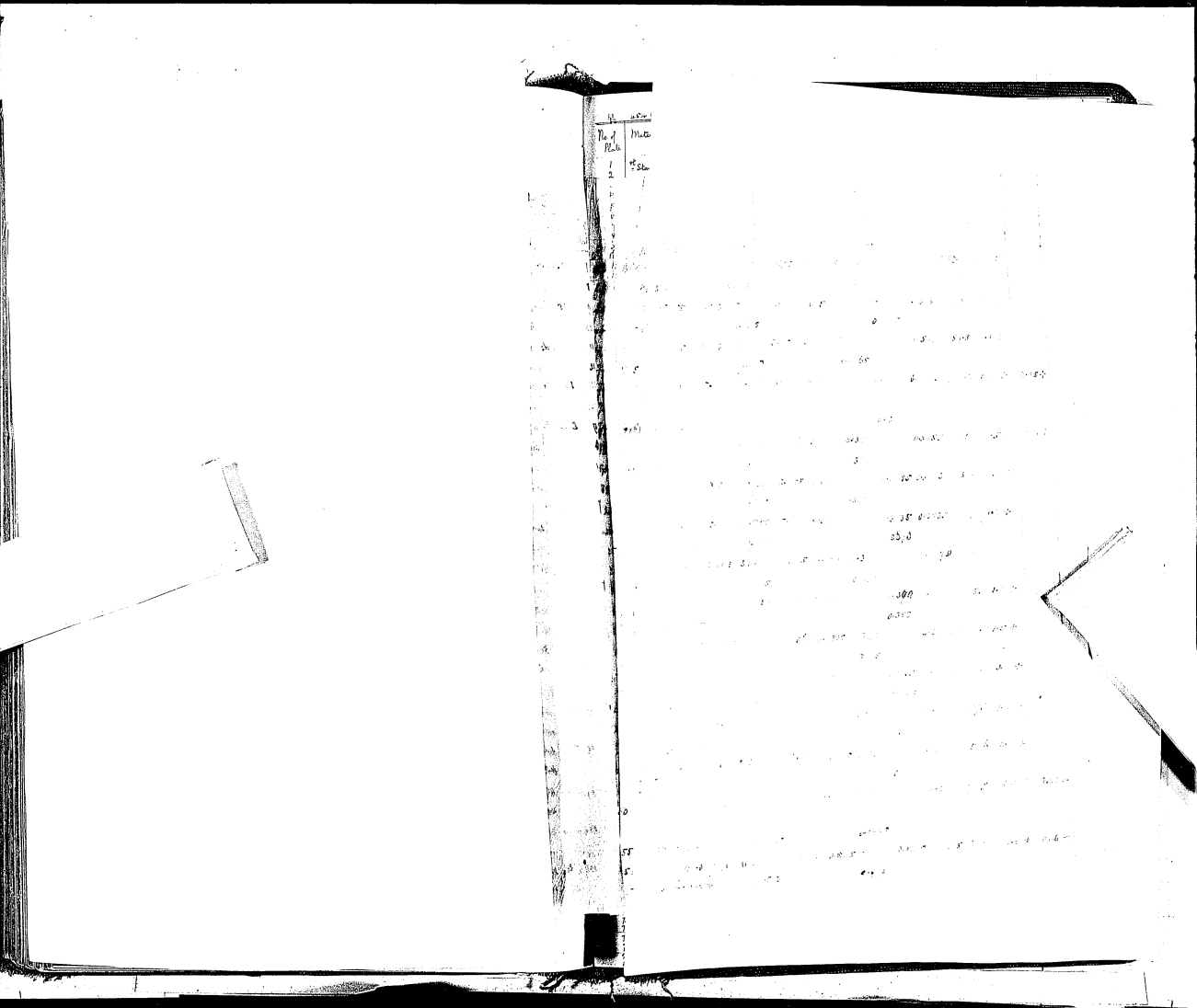
Res. of strip in rt. Rd. arm 0·09945Ω

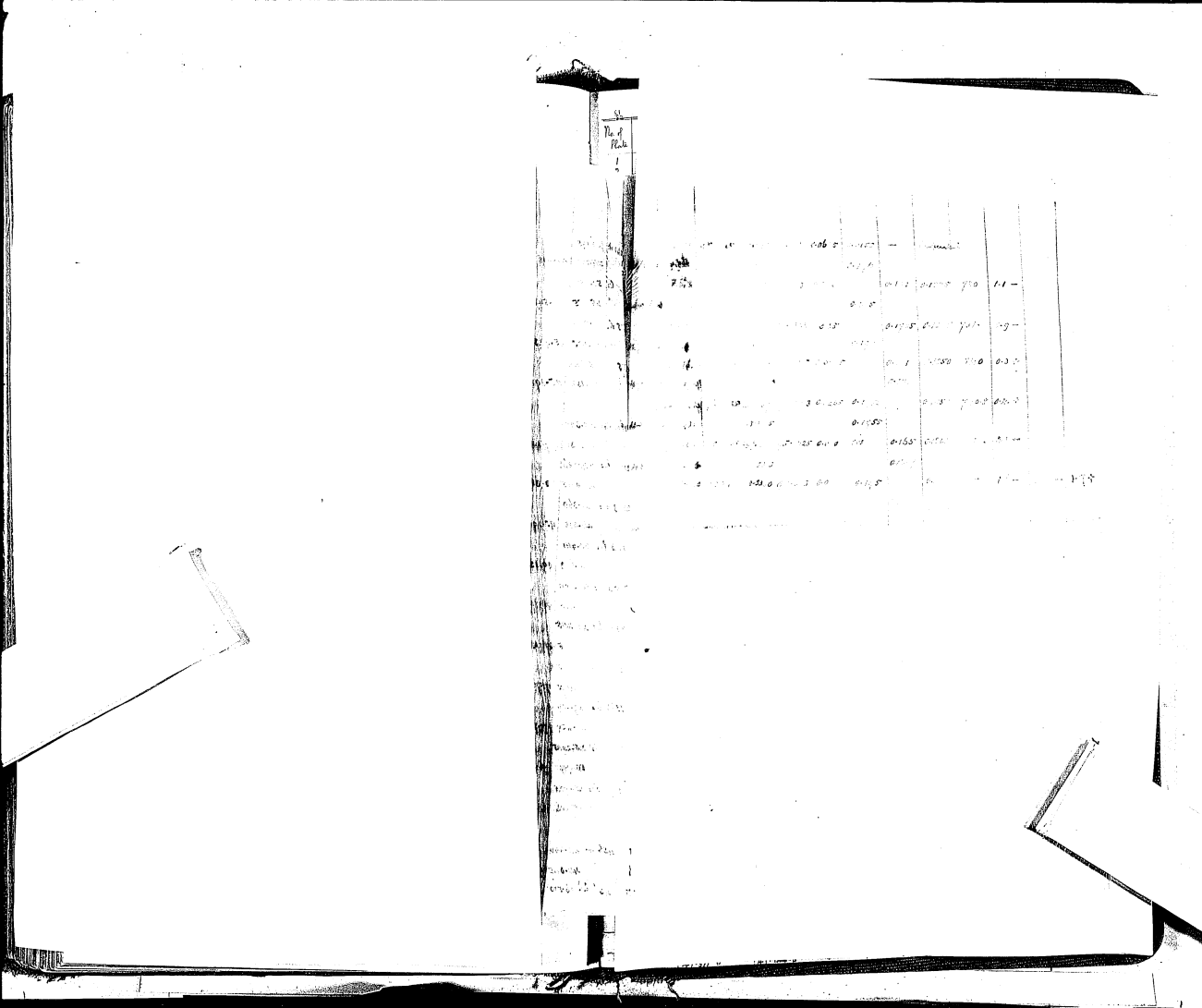
" " eford " " " 98·05Ω + 2·5 = 100·55Ω = 100·65 with shunt

Ratio $\frac{9945 \times 10^{-2}}{10065 \times 10^{2}}$ = 9.882×10^{-4}

For 1224 mgms transferred in the main cct. 1.2093 mgms in the bottle



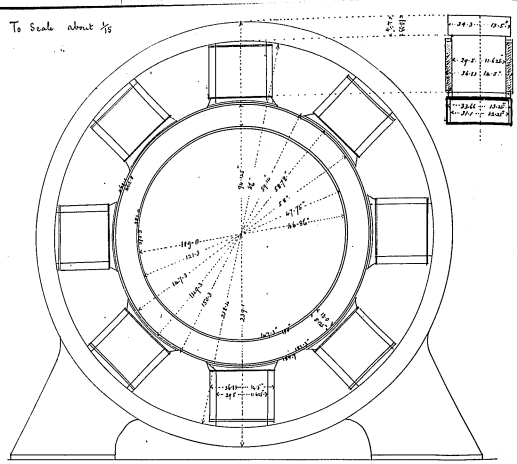


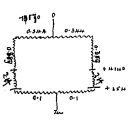


Test of 98.5lbs Pottsville Mortar on Couch 12th May — (a) 0.9236

No. of Plate	Mean	Measured Weight in Air	Measured Weight in water	Measured Weight of Pottsville	Measured Weight of couch	Couch gain	Gain	Loss	Mean Transfer	Amplitude	Discrepancy Ratio	Young's Modulus Discrepancy Ratio	Mean general ratio
1	Standard	449.113 447.247	96.362	168.237 168.152	0.085	0.0295	0.905	0.876	0.8905				
Eqt Standard		448.1680 448.2477	93.2385	167.227 168.224	0.997	0.1067	0.8919	0.8625	0.8772	737.7	738.9	(b) 1.0228	1.0165
Equipotl		447.3743 448.3065	95.7335	166.7161 169.020	2.304	0.0768	0.6595	0.6624.8	0.6419		720.8	(a) 0.9894	
1354 rt		446.2046 449.0587	96.4770	165.760 170.744	4.984	0.0225	0.7715	0.7461	0.7590	759	1.029	(a)	
1354 lt		447.0673 447.7475	96.8165	169.135 169.975	0.840	0.026	0.768 0.7	0.7400	0.7680	768	1.027	(b)	
1434 rt		448.4416 449.226	98.192	168.2095 170.0114	1.8019	0.0225	0.769	0.7435	0.7558	755.8	1.0245	(c)	
1414 rt		447.4992 449.7893	97.781	168.759 169.036	0.277	0.0114	0.769	0.7593	0.7612	761.2	1.032	(c)	
2124 rt		449.578 449.831	99.109	169.196 170.220	1.024	0.007	0.389	0.382	0.3855	771.0	1.025	(a)	
2124 lt		446.286 449.0982	93.386	166.679 168.5734	1.894	0.019	0.388	0.3685	0.3783	9.756.6	1.0257	(a)	
1343 lt		447.2220 449.096	96.3035	166.577 169.860	3.283	0.0814	0.764	0.727	0.7455	745.5	1.0105	(a)	
1434 lt		446.4852 448.5981	95.085	167.261 167.8214	0.560	0.030	0.7158	0.7144	0.7600	760	1.030	(a)	
2123 rt		448.3600 449.9380	95.209	168.7035 169.5705	0.867	0.019	0.3895	0.3635	0.3735	747	1.0125	(a)	
2123 lt		449.4610 449.6730	99.1380	169.1016 170.0721	0.971	0.040	0.389 Average	0.3584	0.3784	758.4	1.0269	(b)	
1365 rt		448.5244 449.3275	97.8825	167.803 168.1085	0.306	0.026	0.7680	0.741	0.7545	754.5	1.023.0	(c)	
1365 lt		446.6025 448.3695	94.9701	167.376 167.632	0.256	0.033	0.7735	0.7375	0.7558	755.8	1.02240	(c)	
2100 rt		449.000 449.110	98.110	169.385 169.7278	0.343	0.026	0.385	0.360	0.3728	746.80	1.0149	(a)	
2100 lt		447.2450 448.785	97.0312	167.867 169.176	1.309	0.0315	0.391	0.388	0.3705	749.0	1.0163	(b)	
1357 rt		449.6135 448.7875	99.203	168.622 169.5535	0.931	0.033	0.768	0.7315	0.7498	749.8	1.0163	(c)	
1357 lt		447.1492 450.4724	97.967	166.761 167.2210	0.459	0.0214	0.768	0.7310	0.7495	749.5	1.0160	(c)	
1363 lt		449.259 448.1139	97.701	168.8965 168.8350	0.061	0.021	0.387	0.3625	0.3758	749.6	1.0162	(b)	
1356 rt		446.6650 449.7641	96.4412	167.916 170.2208	2.305	0.0205	0.759	0.732	0.7465	746.5	1.012	(a)	
1363 rt		448.6825 447.4175	95.7035	169.083 166.6714	2.412	0.0335	0.3945	0.3635	0.3815	763	1.0342	(b)	
1376 lt		447.259 448.9214	96.2114	168.207 169.2229	1.015	0.763	0.747	0.755	755	1.0233	(b)		
2122 rt		448.2855 450.7490	96.1295	168.6400 170.5573	1.917	0.0265	0.3915	0.366	0.3788	757.6	1.0270	(a)	
2122 lt		448.985 448.206	97.193	168.6241 168.598	0.026	97.217	0.387	0.361	0.3714	748	1.0140	(b)	
1418 rt		448.555 447.248	93.8214	167.1802 166.035	1.145	0.0125	0.767	0.753	0.760	760	1.0220	(a)	
1418 lt		447.511 448.975	96.487	168.280 168.233	0.047	0.026	0.769	0.722	0.756	756	1.0249	(a)	
1426 rt		448.4466 448.8935	96.8295	168.6205 167.997	0.623	96.550	0.0205	0.1965	0.1745	762	1.0058	(a)	
1426 lt		446.8700 449.4732	95.9732	166.5703 169.498	2.928	96.062	0.0685	0.0155	×	–			
1364 r		448.298 447.2614	98.5585	168.5998 170.032	1.433	98.583	0.0275	0.768	0.7538	753.8	1.0210	(c)	
1364 l		447.281 449.1419	96.700	168.003 168.6765	0.673	96.7195	0.0195	0.762	0.7325	732.5	1.0473	(b)	
1449 r		448.9140 448.331	97.272	169.1324 168.160	0.972	97.293	0.023	0.194	0.173	0.1825	730	0.9895	(a)
1449 l		448.922 447.4268	96.309	169.077 167.576	1.501	96.3325	0.0235	0.195	0.1905	0.1928	731.2	0.9911	(a)
1347 r		449.195 449.222	98.318	168.11574 169.0823	0.9249	98.1111	0.0246	0.7645	0.741	0.7538	753.8	1.022	(c)
1347 l		450.687 448.8256	96.5743	169.4267 167.116	2.310	96.568	0.025	0.766	0.729	0.7525	752.5	1.020	(b)
1477 rr		448.667 449.561	98.2285	168.2866 169.390	1.103	98.255	0.0165	0.199	0.171 0.1955	0.1850	740	1.093 1.0760	(a)
1477 lr		448.3095 448.0085	96.4405	168.2235 168.229	0.005	96.4465	0.0205	0.1955	0.1885	0.1933	742	1.0058	(a)
1375 r		448.728 447.198	95.423	167.1992 167.963	0.763	95.952	1.029	0.763	0.7585	0.7533	753.3	1.0211	(c)
1376 l		448.234 447.156	95.391	169.0105 166.6030	2.407	95.419	0.027	0.768	0.7625	0.7603	762.3	1.0332	(b)
1426 r		447.911 447.3911	95.5425	168.1265 167.1965	0.930	95.2725	0.030	0.1955	0.1550	0.1803	721.2	0.9775	(a)

To Scale about 1/15





Circuit reluctance

armature	0.2
Air	2.28
Core	0.78
Keeper	0.69
	3.948

$\frac{}{3.948} \times 3.538 \times 10^8 = 21,050$ = 16840 amp turns
= 8420 on each spool.

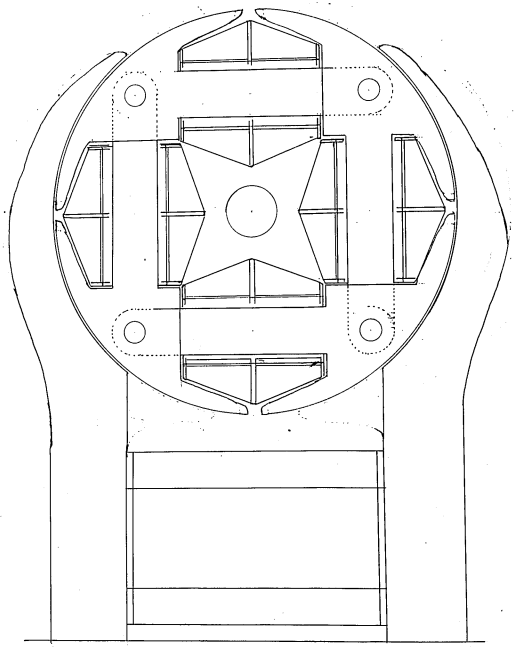
The polar PD across the air gap is $5000 \times 1.5 = 7500$
- armature PD. (superior limit) is $\frac{1}{0.8} \times 48 \times \frac{683}{8} = 5124$

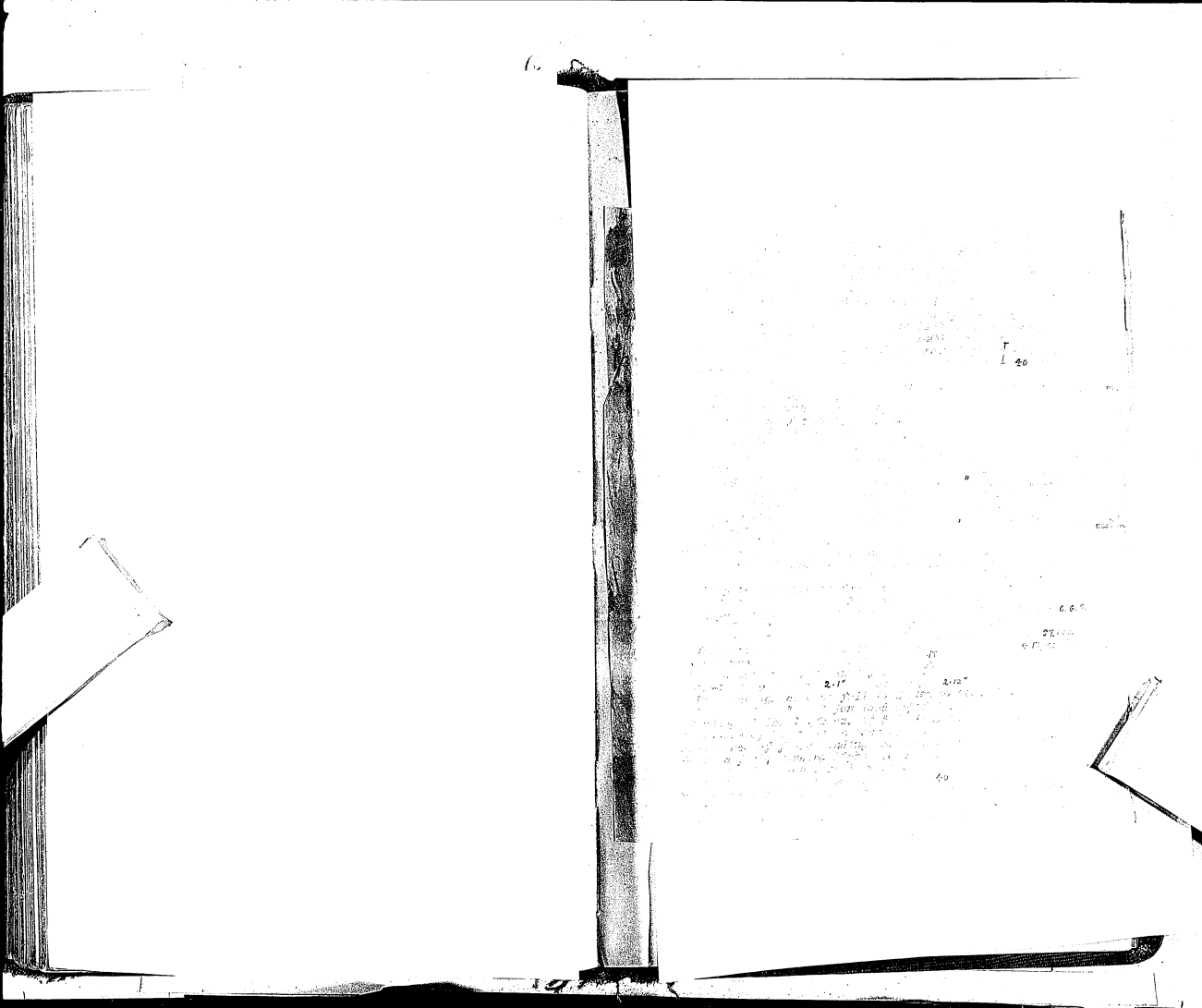
In the formula $w = \frac{2}{11} \frac{Bl}{s}$;
$s = \frac{3}{4} \cdot 1.5$;

Data of the new Octopolar 100 KW. Direct Driven Dynamo (166)
as proposed by Schenectady Works 30th May 91.

Octopolar gramme ring. Cast steel field. Disk armature.
172 r/pm = 28.6 r.p.s. Peripheral speed 1342 kmi = 528.5" - 44.0' p.sec.
Turns on armature 768 — 96 per segment
Current density (1¼ per cm. of armt. cir.) 140.
Section of bar 60,000 sq. mil.
Intensity in air gap 5000.
Flux 3.538×10^8 in armature or 7.078×10^8 usefully through each pole.
E.M.F generated 155.9 volts.
Breadth of armature body 13.5" 34.3 } Mean dia 134.3 cms Mean circ 422
Radial depth - - 5.0625" 12.87 } Gross section of body 1424.1 sq cms
Volume of armature 186,100 c.c.
Section of sheet iron disks 372 sq cms reduction factor 0.8144
Mean density in armt. at full flux 9500.
Diameter of cores 11.625" 29.5 cast steel. Sectional area 683.5 106 sq in.
Section of keeper 13.5" × 4.0625" = 54.85 sq in: 34.3 × 10·33 = 3542 sq cms.
Length of one turn on armature 3.05'
Total length on armature 231.2'.
Resistance of armature hot $\frac{10,145 \times 2312}{60,000 \times 144} = \frac{2.1685 \times 10^7}{3.24 \times 10^8} = 6.37 \times 10^{-3} = 0.00637$ ω @ 100°C
Full load current 670 + 13 = 683 amp.
Drop in armature at full load = 4.33 volts
Power lost - - - = 2960 Watts.
Rise of temperature of armature = 60°C. at full load
Resistance of armature = $\frac{9.276 \times 2312}{60,000 \times 144} = \frac{21478 \times 10^4}{3.24 \times 10^8} = 5.659 \omega \times 10^{-3} = 0.00566 = @ 60°C$
Drop in armature @ 60°C. under full load = 3.87 volts
Power lost - - - - - - = 2640 Watts.
Watts per sq in: of radiating surface 2640/1213 = 2.185
- - - cm. - - - 0.085 Watts.
Amp turns on each core at full load 7600
Current in shunt field 12.66 ?
Res: of field hot 9.58 ω
Watts per sq. in. on field 0.28 per sq. cm. 0.0434 = 23.0 sq. cm per Watt.
Estimated rise of temp. on field 22.4° C.
Total weight of copper on field 900 lbs: # 10 B&S.
Watts lost in field 1670, in res: loc. 22? . = 132 volts in field, 15 in box.
Polar angle 31° acc 41 cms. Area 41 × 34 = 1394 sq. cms say 1400
Interpolar 6.5 cms. Interpolar reluctance 17/1400 = 1.07 millihenrys.
Armature reluctance 50 cms length /372 at a density of 9500 and
reluctivity 1.14 ml. = 70/372 = 0.19 ml. say 0.2 ml.
Adding the magnetic potential at the centre of the armature segment sees,
the potential of the armature underneath this pole is 0.1 × 3.538 × 10^8 = 3538
- - - - polar surface - - 1.17 × 2.538 × 10^8 = 4140
Reluctance of core 40 cms. / 342 , at B = 13,750 ρ = 3.3 ml. = 0.3249 ml. × ρ.
- - - 76 - / 354 at B = 13,220 ρ = 3.2 - = 0.687 -

The density in the core will be about 14,600.
Increasing the area 7% gives 731.4 sq cms. = 12" diam:
There are 600 turns of wire on each core
Increasing the area 16% gives 754 sq cm = 31 cms = 12.21"
Half an inch more depth in the keeper would mean 9.5 × 13.5 × 3.142 × 0.3 = 120
The keeper was subsequently increased to 4 ½".
Hysteresis in armature 1255 Watts.





Determination of the Electromagnetic circuits for a fan motor to operate on 120 volts pressure

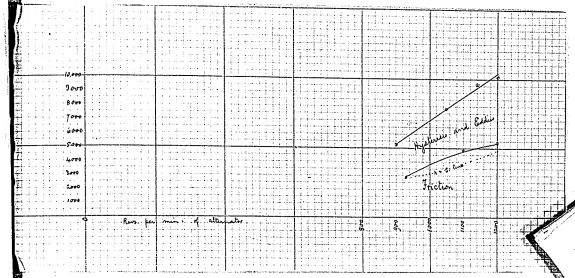
The revolutions per minute to be 1100. = 18·3 per sec.
" open voltage of the armature to be 90.
" number of wire all round = $\frac{9 \times 10^9}{768 \times 10^8 \times 1.933 \times 10^6} = \frac{9 \times 10^9}{1.498 \times 10^6} = 5000$
" cross section of iron = 2·140 sq cms in armature.
useful flux = 16,000 × 2·4 × 2 = 76,800
turns per bobbin will be 5000/8 = 625
winding space section in each half bobbin did 2·3 × 0·9 = 2·07 sq cms
" " " " " 0·92 × 0·350 = 0·322 " ins
" " per wire = 0·322 ÷ 625 = $5·5 \times 10^{-4}$ sq ins. = $7·365 \times 10^{-2}$ diam ins
= 0·023" s.c.c. to 0·016". # 27 B.W.G.

The cross-section of the field magnet should be 80 sq cms
diameter " " " 3·6 cms.
" " " 1·42".

Mean winding diameter 1·75" circ. = 5·5" = 0·458'. #
Total length of wire 2290' ~~= 0·0~~ $7·758 \times 10^{-4} \times 2·29 \times 10^3 = 1·78$ lbs.
resistance " $2·29 \times 10^3 \times 4·612 \times 10^{-2} = 13·38 \times 10 = 133·8\,\omega \div 4 = 33·4\,\omega$

Reluctance of air gap with 0·1 entefer = $\frac{0·2}{10·5 \times 15} = 0·01$, and to force 76,800 lines through this will take $768 \times 0·8 = 614$ at $\frac{4\pi}{10}$ or 0·7 amp
9,840 turns

There are 11 c.ins. of exiting space on the magnet = 2 lbs; and the wt. of the coil hot = 40 ω = 20 ω per lb. = 2ω B.W.G. 0·022" s.c.c. to 0·029
The mean turns = 0·5' there will be 110 turns and 17 layers = 1870
turns = 935'. $2·44 \times 9·35 = 22·8\,\omega$
With # 25 B.W.G. 0·020" s.c.c. to 0·027" there will be 125 turns and 18 layers
2250 turns = 1125' × 0·02952 = 33·2 ω.
With # 26 B.W.G. 0·018" s.c.c. to 0·025" there will be 136 turns and 20 layers
2720 turns = 1360' × 0·036445 = 49·6 ω. Say 40 ω of this wire
$2720 \times \frac{4}{5} = 2176$ turns and 16·32 pti = about 1·1 lb. wire


12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Revs. per min. of alternator
Hysteresis and Eddy
Friction

Experiments with the Alternator.

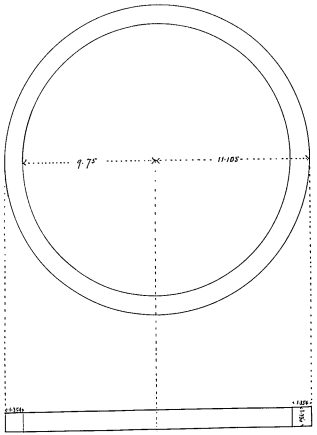
The machine was operated on the 4th June by the #12 machine as it acting as a motor and the other #12 as a dynamo driven by the engine. With the brushes field and 12.7 of excitation, the motor absorbed 90 amps. @ 98 volts = 8820 Watts running at 1000 rpm and generating about 1100 volts effective.

Took following power readings

Volts at m.t.	Current this motor	Energy in motor	Energy absorbed above motor fric	Speed of Alternator	Current in Alternator field	Current in alternator	Energy absorbed in alternator at η = 0.95		
100	11	1100	0	0	0	0			
104	40	4160	3060	932	0	0	2906		
126	50	6300	5200	1100	0	0	4940		
135	50	6750	5650	1200	0	0	5368		
101.5	65	6595	5498	900	1.87	0	5223		
125	75	9375	8275	1050	"	0	7860		
127.5	80	10,200	9100	1020	-	0	8644		
140	80	11,200	10,100	1140	-	0	9594		
144	81.5	11736	10636	1200	-	0	10,100		

On 5th June operated the no1. Edison Transformer successfully, lighting up 12 lamps of 16 cp (at pds between 50 + 75 volts). The transformer gave a rather loud sound. It attained a temperature of 75° C. after running for two hours.

Plan and Diametrical section of Ring no 1. Scale ½.



Internal radius	9.75	Diameter	19.5 Circ. 61.26
External "	11.105	"	22.21 " 69.78
Mean "	10.4275	"	20.855 " 65.52
External area	387.42		
Internal "	298.65		
Annular "	88.77		
Depth of ring	1.336	(0.526")	
Breadth " "	1.354	(0.533")	
Cross section "	1.809		
Volume "	118.6 c.c.		
Weight in air	920 gms	919.5 gms by steel room scale	
" Toluene	803 "	@ 17°C.	
Volume	117 c.c.	by weighing	
sp. g.	7.864		

An indentation at one place on the edge amounting to 0.13 would reduce the cross section locally by 0.009 so that the cross section may be assumed at 1.8 sq. cms

Two opposite secondary windings each 50 turns. with central platinoid.

Primary 1st	336	583	Total
2nd	314		
3rd	347		
Outside	16	337	986

$\frac{1.257 \times 986}{65.52} = 18.81$ = H per amp: with all primary in ckt.

Particulars of Magnetic Test Rings received from Stratton & Co. (169)

8 rings were received from Stratton on the afternoon of the 4th June. They were welded from bars of different composition, and marked 1 to 8. They were very irregular in section and were therefore turned up to a rectangular section in the lathe.

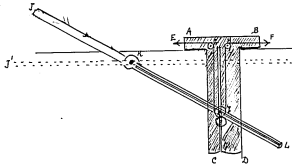
The analyses of the metal in these rings were received in a letter from Stratton dated the 5th June

	C.	Ph.	Mn	Si.	S.	
Bar # 1	0.13	0.008	0.31	0.01	0.029	} For effect of Ph.
2	0.13	0.088	0.39	0.01	0.05	
" 3	0.33	0.013	0.46	0.01	0.026	} For effect of Ph + Mn
" 4	0.28	0.114	1.12	0.02	0.043	
" 5	0.15	0.018	0.53	0.01	0.013	} For effect of C.
" 6	1.05	0.007	0.19	0.01	0.013	
" 7	0.39	0.088	0.77	0.04	0.047	} For effect of Si.
" 8	0.44	0.037	0.82	0.26	0.032	

Test of # 1 Ring

No of Obs.	Source of EMF	EMF	Capacity	a	Mean Throw	q per div	
	1 Bl. 6.0 19.8°C	1.4325×10^{9}	2.9×10^{-11}	2.865×10^{-7}	211.2	1.358×10^{-3}	

No. of Obs.	Grad.	Obsvr.	Amplitude	H	No. of Throws	Mean Throw	Res in coils	Resist of circt.	$q \times 10^{-8}$	q	$\mathcal{L}$	H	μ	$\mathcal{L}$ K in $^{-3}$
1	0.09981		1.0758	1.417	5	19.9	0	5250	2.698	14.16	787	1.417	555.5	1.80
2	0.13165		0.09926	1.867	5	143.4	0	-	5.885	31.90	1717	1.867	919.6	1.087
3	0.20365		0.1531	2.885	5	130.3	0	-	17.67	93.79	5155	2.885	1787.	45.576
4	0.24933		0.3162	5.947	5	265.1	0	-	35.94	194.60	10,480	5.947	1762	45.675
5	0.59247	0.088	0.7225	8.474	5	353.4	25,000	30,250	7.202	21.900	12,170	8.474	114.36	0.6964
6		0.099	0.515	9.687	4	93.9	12,500	17,750	12.73	22,570	12,550	9.687	129.5	0.7722
7		1.2335	1.203	22.67	5	112.8	-	-	15.30	27,150	15,080	22.67	663.2	1.508
8		0.452	2.333	43.89	4	120.6	-	-	16.35	29,020	16,120	43.89	367.14	2.722
9		1.68	8.668	163.0	5	139.4	-	-	18.90	33,540	18.630	163.0	114.2	8.756



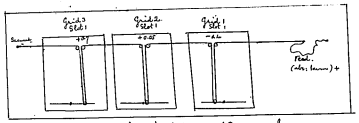


Diagram representing one unit in position with levers at zero, frames clamped, and ready for knot.

There are 3 wires parallel, only one shown.

$b = a \tan\theta$

If $\tan\theta = x$

$b = ax$

On the design of a machine for solving simultaneous Linear Equations, and determinants 7th June 91. (170

Sir W. Thomson has given in an Appendix to Thomson & Tait's Natural Philosophy a description of a very ingenious machine for the same purpose. It seems probable however that if the machine here to be described, and which operates on a different principle will work at all, it will be simpler and more accurate than Thomson's.

A metal grid is used for each equation. If there are four simultaneous equations or 4 unknowns, there will be four grids in use, although a machine may be arranged for any number of unknowns and have any number of grids without requiring any change for the use of a lower number.

Each grid has as many parallel slots as there are grids in the machine. Frame slides and are definitely clamped in these slots, one in each, ~~one for positive and the other for negative values of the~~. Each frame AB has two strong uprights CD separated by a space in which slides with working fit, the axle of a movable pulley I. A cord EF preferably of thin strong and inelastic wire runs over this loose pulley and the fixed pulleys G & H. The position of this pulley I in the groove is determined by a guide rod KL pivoted at K, whose zero is horizontal J'L'. A strictly parallel guide rod on the same axis runs in each slot of the grid.

To operate the machine, all the grids are fixed in line. Cords or wires are then run through each set of 3 pulleys in each grid, one wire for each ~~groove~~ slot, so that if there be 6 grids, there will be 6 wires each in its corresponding line of slots. The wires are secured at ~~the~~ one end, ~~of~~ the extremity of the last grid. The frames AB are now set to scale in their groove at the coefficient of their ~~representative~~ unknown on the right of K if +, to the left if −, with the guide rods all horizontal. The wires are now pulled taut and brought to a zero point on the edge of the 1st grid. Lengths of wire equal to the absolute terms in each equation are measured off to scale and fed in if + or prepared for hauling out if −. All the feeds are then clamped.

The guide rods have now to be manipulated until the slack in the wire entirely disappears. This must be done by trial. A fair certainty slack wire has to be tightened by hauling over the guides in the grids of its high coefficients and vice versa. The operation could be performed unerringly and immediately with two grids and two wires, with a little more delay for 3 grids and wires, and probably more and more delay with each additional equation and unknown. but perhaps the operation would always be successful. When attained the rods would be clamped, and the tangents of the angles from zero described by each rod would be the value of each corresponding unknown.

Kennelly Notebook #5

This notebook covers the period June-December 1891. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, condensers, fan motors, alternators, and dynamos. In addition, there are extensive notes and design drawings relating to electric traction, including tests of Edison General Electric street car motors, and data regarding low-voltage street railway systems. Also included are comparisons of Westinghouse, Thomson-Houston, and Edison transformers; data regarding the electromagnetic properties of iron; and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "V" and "1891." The book contains 159 numbered pages. Some pages were removed before the book was paginated. Numerous graphs, blueprints, tissue copies, photographs, and other items have been pasted into the book.

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Record Book

of

Observations, Calculations, and Data

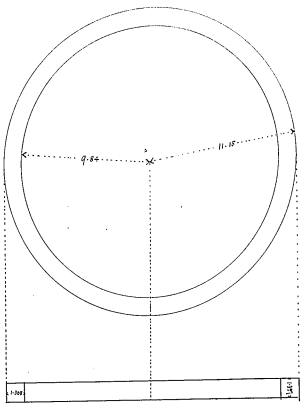
compiled in the Galvanometer Building

Edison Laboratory, Orange N. J.

commenced 7th June 1891

completed 31st December 1891.

Plan and Diametral Section of Ring #3. Scale 1/2



External Rad: 11.152 , Diam: 22.304 , Circ: 70.08
Internal - 9.843 - 19.685 - 61.85
Mean - 10.498 - 20.995 - 65.96

External area covered 391.57
External - - 304.79
Annular - - 86.78
Width (Mean of 8) 1.397 (8.550")
Rad: Breadth (- -) 1.308 (8.515")
Cross section 1.828
Volume 164.86
Weight in air 934.5
- - Ref H_2O at 17°C 815.45
Volume by weighing 119.05

Sp. g. 7.85

Edges depressed at one spot
Depressions 0.073 and 0.052
completing t mm 0.005 and 0.027 mm = 0.077 reducing the cross section locally to 1.82

1.397" × 1.9216
1.308" × 1.7109
3.6624 √ = 1.914"

Two secondary coils, each 50 turns
Primary windings

	1st layer	333	
	2nd -	329	662 brought out
	3rd -	331	
	4th -	331	
		994	331 - -
			993

$H = \frac{994 \times 1.257}{65.96} = 18.932$ per amp.

333		
329	662	brought out
331		
993		

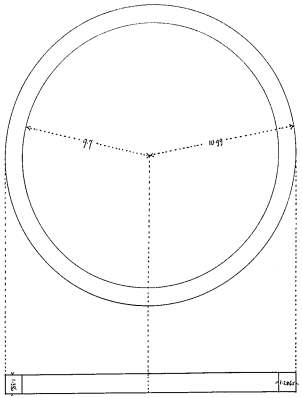
Magnetic Test of Steelton Welded Ring no 3.

7th + 8th June 1891

No. of Obs.	Sect. 0.1745	Obsvd 0.1938	Amplitude	Time of primary	No. of Throws	Mean Throw	Rep. coil & Ext.	Rest of q. coil	N	φ	ℒ	H	μ	ρ	Secondary turns
									$\times 10^{-9}$					$\times 10^{-3}$	
1	0.0963		0.0747	331	3	2.3	0	5275	3.287	173.4	95.3	0.1471	2.02.3	4.943	50
2	0.1365		0.1021	-	4	3.3		"	4.718	248.9	136.7	0.6444	2.12.2	4.713	
3	0.1989		0.1542	-	6	5.2		-	7.436	392.1	215.5	0.973	2.21.5	4.515	
4	0.2710		0.2132	-	6	13.2		-	18.87	995.4	547.0	1.976	276.8	3.613	
5	0.6068	0.070	0.4705 0.4644	-	5	24.1		-	34.645	1817.0	998.2	2.965	336.6	2.971	
6		0.095	0.1492	-	1	27.1.0		-	44.32	2,338.0	1285.0	3.124 3.092	411.0 411.5	2.433 2.427	
7		0.160	0.1257	-	5	102.1		-	145.95	7698.0	4230	5.265 5.205	803.1 812.6	1.245 1.231	
8		0.237	1.2218	-	5	173.3		-	247.7	13,065	7178	7.928 7.745	917.0 926.5	1.090 1.079	
9		0.3345	1.726	-	5	229.2		-	327.6	17,280	9494	11.00 10.87	983.3 973.8	1.1.87 1.1.77	
10		0.562	2.900	-	5	151.1 298.2	5000 0	16,275 32,15	216.0 426.3	33,190 22,440	12,195 12,360	18.49 19.24	659.6 668.4	1.5.18 1.4.69 1.4.49	
11		0.720	3.766	-	5	163.8	5000	102.75	234.15	22,060	13,230	24.01 23.77	557.0 563.0	1.8.15 1.7.91	
12		0.724	3.736	993	5	202.9	-	-	29.0.0	29,790	16,370	31.111 30.70	229.1 231.6	4.365 4.319	
13		1.675	8.642	-	3	227	-	-	324.5	33,350	18,325	165.3 163.6	110.9 112.5	9.017 8.924	

No. of Obs.	Source of EMF	2MK at temp.	Capacity	Mean Throw	Q	q. per div:	R. of q. at temp.
12	1 Bb. @ 2114	4.31×10^{4}	24×10^{-15}	2082	$2.86 2 \times 10^{7}$	1.14295×10^{-3}	5275

Plan and Diametral Section of Stretton Ring #2.



Ext: Rad: 10.987 Diam: 21.974 Circ: 69.052
Int: 9.7 " 19.4 " 60.95
Mean 10.3435 " 20.687 " 64.99
External area covered 380.0
Internal " " 298.59
Annulus " " 84.41
Width Mean of 8 readings 1.386 (0.5455")
Radial width " " " 1.2865 (0.5066")
Cross Section 1.783
Volume 118
Weight in air 937.5
" Soft H_2O 0°C 782.65
Volume by weighing 114.85
Sp. g. 7.816

Edges depressed at one place [illegible] 1.386" + 1.921 / 1.2865" + 1.655" 3.576" / 1.89 cm

Depression 0.821, mean but 0.0146, readings area locally to 1.7884

Two secondary coils each 50 turns

Primary winding 1st layer 308
2nd " 306 6 1/4 brought out
3rd " 303
4th " 3 307
921

$H = \frac{921 \times 1.257}{64.99} = 17.81$

Magnetic Test of Stretton Welded Ring #2. 8th June

(2)

No. of Sets	Source of EMF	EMF @ temp.	Condr.	a	Mean Thour	ap. per div.	Res. of G.
13	1 Pcb. @ 20°C	$1.4.31\mu$ Kilo	$2\,\Psi \times 10^{-15}$	2.8628×10^{-7}	205.8	1.391×10^{-7}	52.66 ω

No. of Wn.	Total Length Turns.	Sec: (2π r²)	Shunt (0.1Ω)	Amps.	Th Therm	Mean Thour	φ	R. in circ:	R. of ckt:	φ	∫φ	H	μ	$\frac{I}{\rho} \times 10^{-3}$
							10^{-8}							
1	307	0.0963		0.07147	3	2.7	3756	0	5266	1978	111.8	0.4442	251.8	1.97
2	"	0.13165		0.1021	3	4.3	5981	0	"	315.	178	0.606	2937	3.005
3	"	0.20406		0.1582	4	8.0	11.13	0	"	586.	331	0.939	352.5	2.837
4	"	0.42791		0.3318	5	28.6	39.79	0	"	2095	1185	1.97	601.5	1.663
5	"	0.60681	0.492	$\frac{0.4700}{0.5280}$ $\frac{0.4704}{0.4704}$	5	77.0	107.1	0	"	5640	3190	$\frac{2.793}{2.793}$	$\frac{1142}{1132}$	$\frac{0.8757}{0.8836}$
6	"		0.229	$\frac{1.243}{1.162}$	5	267.1	371.6	0	"	19,570	11,070	$\frac{7.390}{7.818}$	$\frac{1149}{1077}$	$\frac{0.8676}{0.9284}$
7	"		0.392	$\frac{2.132}{2.023}$	5	763.3	1062.1	5000	10,266	23,310	13,180	$\frac{12.66}{12.01}$	$\frac{1054}{1098}$	$\frac{0.9606}{0.9107}$
8	921		0.390	$\frac{2.121}{2.013}$	5	745.5	1037.9	"	"	27,920	15,790	$\frac{37.77}{36.86}$	$\frac{418.}{428.4}$	$\frac{2.392}{2.271}$
	"		1.715	0.3246	3	228	317.1	"	"	32,550	18,410	$\frac{166.4}{164.6}$	$\frac{119.8}{120.9}$	$\frac{8.358}{8.268}$

Measurement of the Candle-Power of a Locomotive Engine Headlight intended for use at Ogden mines.

This was a star head-light # 925. a lamp with a circular wick is placed at the focus of a parabolic nickelled copper reflector. The lamp compared in the photometer against 2 standard candles shewed 22 c.p. It is intended to replace this by a 100 cp el. lamp.

Measurement of some special-german-silver resistance wire for the Edison Manufacturing Co. Silverlake

One sample 453 cms: 0.058" = 0.1473 diam = 0.01705 area has 1 ω res. @ 19°C.
Res: per cm: 2.2075 × 10⁻² ω = 2.2075 × 10⁷
" " c.c. = 2.764 × 10⁵

The other sample 344 cms. of 0.049" = 0.1245 = 0.012106 area has 1 ω @ 19°C.
Res: per cm. = 2.907 × 10⁷
" " c.c. = 3.537 × 10⁵

Comparison of throw on Ballistic Galvanometer from Standard Wooden ring, and from Clark cells. 8th June.

No. of Obs.	Source of emf.	EMF at temp	Capacity	q.	Mean throw	q. per div.	Res. of Galv.
9	1 C.C. @ 22.5°c.	1.430×10^{8}	2.0×10^{-15}	2.86×10^{-7}	200.77	1.4248×10^{-9}	5290 ω

	Obach	Amp.	H	Area	φ	Turns.	Res. of G: cct:	Mean throw	q.	φ	Discrepancy		
	0.444	2.291	26.51	11.807	3130	2000	5334	165	2.35×10^{-7}	3125	1.0019		

Test of a Condenser # 808 $\frac{1}{3}\,\mu f$ by Elliott Bros. 12th June 91, for Schenectady.

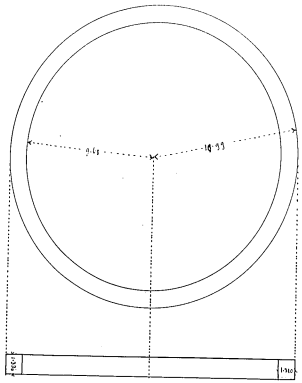
By bridge 1000/1000 50 volts and secohmmeter 0.3296 μf @ 26°c.

Insulation test 10 volts Ballistic G: full charge 235 divs: insulated after 60 seconds charge for 600 seconds (660 from 1st charge). The second charge after 600 secs. leakage was 75 divs.

$$R = \frac{600}{0.3 \log_e \frac{235}{160}} = \frac{600}{0.3 \log_e 1.469} = \frac{600}{0.3 \times 0.385} = \frac{600}{0.1055} = 5687\,\Omega$$

Time of fall to half charge $= \frac{0.30103}{0.16702} \times 600 = 1081$ secs.

Plan and Diametral Section of Welded Ring #4 1/2.



Int: Rad. 9.68. Diam: 19.36 Circ: 60.82
Ext. " 10.99 " 21.98 " 69.05
Mean " 10.335 " 20.67 " 64.93

External area covered 294.38
Internal " " × 379.44
Annular " " 85.06
Depth (mean of 8 readings) 1.396 (0.5496")
Radial breadth (" " ") 1.310 (0.5157")
Volume 118.76
Cross section 1.8285
Weight in air 920.5
" in H_2O 804.2
Volume displ. weighing 116.3
Specific gravity 7.915

Edges depressed at one spot 0.994 1.396" - 1.402
1.310" - 1.7161 3.6649 = 1.911 . 0.0925

Depression 0.0925 area lost 0.005516 reducing the cross section locally to 1.8239
Accepted area 1.82

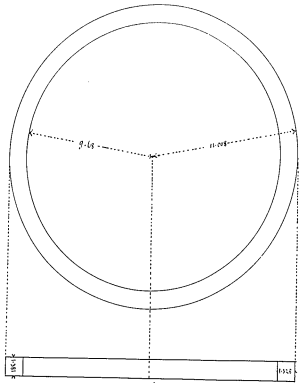
Two secondary coils each 50 turns
Primary 1st layer 320
2nd " 322 642 brought out
3rd " 321 321
Total 963 963

$H = \frac{963 \times 1.25696}{64.93} \approx 18.64$

Magnetic Test of Stretton Welded Ring #4.

No. of Mts.		Source of EMF		E.M.F. at beg.		Capacity		a		Mean Thickness		q for dia.		R. of Galv.	
	q	1 Bloje 22.5°C.		1.42,95 x 10⁸		2.0 f x 10⁻¹⁵		2.859 x 10⁷		199.5		1.4333 x 10⁻⁹		5285 ω	
No. of Obs.	Std. 17720	Obsvd. Ratio	Amplitude	Turns primary	No. of Throws	Mean Throw	Flux added by coil	Flux of 1 coil	q.	φ	b	H	μ	ρ x 10⁻³	Secondary turns
									x 10⁻⁹						
1	0.09624		0.09465	321	4	1.69	0	5295	2.42	127.9	70.3	0.464	151.5	6.601	
2	0.13165		0.1021	"	5	1.7	"	"	2.436	128.7	70.7	0.634	203	4.926	
3	0.20348		0.1578	"	5	3.21	"	"	4.586	242.4	133.2	0.980	135.9	7.358	
4	0.39846		0.3093	"	5	6.4	"	"	9.172	484.7	266.4	1.922	138.6	7.215	
5	0.54246	0.055	0.4210 0.4316	"	5	9.9	"	"	14.19	749.8	412.0	2.616 2.725	157.5 151.2	6.349 6.614	
6		0.121	0.6243	"	5	13.4	"	"	27.8	1469.	807.2	3.88	208.1	4.805	
7		0.24	1.238	"	5	116.2	"	"	166.5	8799	4835	7.692	628.5	1.591	
8		0.32	1.651	"	5	174.1	"	"	249.5	13,195	7250	10.26	706.7	1.415	
9		0.4605	2.376	"	5	238.4	"	"	341.6	18,050	9918	14.76	672.2	1.488	
10		0.363	1.873	963	5	175.2	5003	10285	251.1	25,820	14,190	34.91	406.5	2.460	
11		0.5615	2.897	"	5	191.9	"	"	275.0	28,280	15,540	53.99	287.9	3.473	
12		1.673	8.632	"	4	223.	"	"	319.55	32,860	18,060	160.9	112.3	8.904	

Plan and Diametral Section of Steelton Welded Ring #5.



External Rad: 11·008 Diam: 22·016 Circ: 69·165
Int: " 9·68 " 19·36 " 60·820
Mean " 10·344 " 20·688 " 64·99

External area covered 380·62
Internal " " 294·38
Annulus " " 85·24

Depth (mean of 8 readings) 1·381 (0·5435")
Radial breadth (" " ") 1·328 (0·523")
Cross section 1·834
Volume 117·7
Weight in air 919·4
" " bal 9,0 20°c 802·05
Volume by weighing 117·35

Sp. gr: 7·835

Edges depressed at one spot [illegible] 1·8244 $1·381^2$ = 1·9076
$1·328^2$ = 1·76359
0·67075 = 1·916

Depression 0·092 area lost 0·000846
Reduced Area 1·8255 (Accepted).

Winding 2 Secondaries, 50 turns each
Primary 1st layer 323
2nd " 321 644
3rd " 322 322
966 966

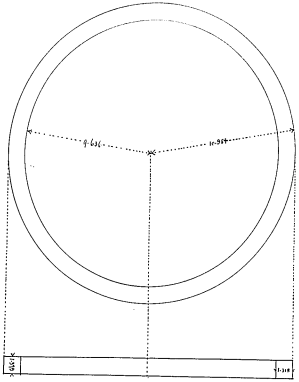
$H = \frac{1·257 \times 966}{64·99}$
= 1·868 per ampere.

Magnetic Test of Steelton Welded Ring #5.

No. of Obs.	Source of EMF	EMF at temp	Capacity	a	Mean Rad	½ Ins. dia	R. of Galv.
16	1 Bb. @ 24°c.	$1·42258 \times 10^{-8}$	2×10^{-9}	$2·8516 \times 10^{-7}$	2·08·45	$1·368 \times 10^{-3}$	5360

No. of Obs.	Std: 17322	Obsd. 24938	Amplitude	Turns	No of Turns	Mean Rad	Ricochet	R. of Coil	q. $\times 10^{-3}$	φ	$\frac{L}{2}$	H	μ	ρ $\times 10^{-1}$	Secondary turns
1	0·09786		0·0758	322	5	4+	0	5360	54·7	293	160·5	0·472	340	2·94+	50
2	0·13758		0·1066	"	5	6·7	"	"	9·17	449·5	269·3	0·664	405·5	2·47	
3	0·21712		0·1683	"	5	11·2	"	"	15·32	821·	449·8	1·078	429·3	2·33	
4	0·48234		0·3774	"	5	43	"	"	58·82	3153	1727.	2·33	741·	1·35	
5	0·7199	0·109	0·5582 0·5822	"	5	130·8	"	"	179·0	9594	5256.	3·4772 3·5822	1512· 1501·	0·661 0·666	
6		0·137	0·707	"	5	168·7	"	"	230·8	12,370	6776.	4·4074	1539	0·650	
7		0·164	0·8462	"	5	207·2	"	"	275·2	14,750	8080	5·27	1533	0·652	
8		0·237	1·223	"	5	132·5	5800	10360	181·2	18,780	10,290	7·616	1251	0·799	
9		0·333	1·976	"	5	162·1	"	"	221·7	22,970	12,588	12·31	1023	0·978	
10		0·380	1·968	966	5	200·3	"	"	274·1	28,400	15,560	36·63	425·	2·353	
11		1·614	8·463	"	5	236·2	"	"	323·1	33,480	18,340	158·1	116	0·821	

Plan and Diametral section of Stretton Welded Ring #6 1/2



External Rad: 10.954 . Diam: 21.908 . Circ: 68.82
Int: - 9.636 . - 19.272 - 60.54
Mean - 10.295 . - 20.590 - 64.69

External area covered 376.97
Internal " " 291.73
Annular - - 85.24

Depth (mean of 8 readings) 1.379 (0.5428")
Radial breadth (- - - -) 1.318 (0.5188")
Cross section 1.817
Volume 117.55
Weight in air 901.3
- Imp H_2O at 70°C 785.95
Volume by weighing 115.35
Sp. g. 7.814

Edges depressed at one spot to [illegible] 1.798 1.318" . 1.7371
1.379" . 1.9016 3.6387 - 1.905

Depression 0.110
area lost 0.0121
Reduction of area to 1.805 accepted area.

Winding, 2 secondaries of 50 turns each
Primary 1st layer 330
2nd . 328 658
3rd . 329 329
987 987

$H = \frac{1.2566 \times 987}{64.69} = 19.17$ per amp

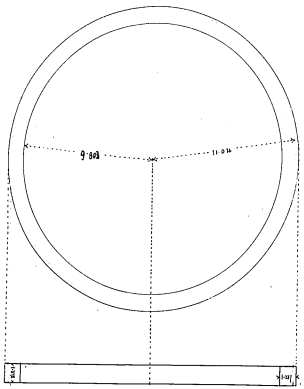
Magnetic test of Stretton Welded Ring #6.

(6)

No. of Dia.	Source of Emf	EMF at temp	Gap	Ω	Mean thickness	φ per division	Reciprocal of G.	
9	1 Bs @ 22.5°C	1.4295 x 10⁸	2.0 x 10⁻¹⁵	2.859 x 10⁷	199.5	1.4333 x 10⁻⁵	5325	

No. of Obs	Std. 0.7752	Obsvd. reading	Amps	No. of turning turns	No. of turns	Mean thickness	Reciprocal load	R. of G. corr.	φ	β	H	μ	ρ x10⁻³	Secondary turns
1	1.09042	+	0.0701	658	4	1.5	0	5325	2.05x10⁻³	114.5	63.4	0.896	70.74	14.13	50
2	0.123		0.0752	"	5	1.9	"	"	2.58	137.4	76.	1.219	62.35	16.04	
3	0.1929		0.1196	"	5	2.4	"	"	3.239	183.1	101.2	1.912	53.03	18.86	
4	0.3919		0.3093	"	5	5.2	"	"	7.453	396.9	219.9	3.953	55.6	17.99	
5	0.5169	0.080	0.4029 / 0.4229	"	5	8.3	"	"	11.895	633.5	351.0	5.122 / 5.277	69.52 / 66.52	14.60 / 15.03	
6		0.212	1.0944	"	5	97.5	"	"	139.72	7440	4122	13.98	2914.9	3.391	
7		0.268	1.383	"	5	131.3	"	"	188.2	10023.2	5553	17.68	314.1	3.182	
8		0.350	1.806	"	5	170.9	"	"	244.9	13040	7226	23.08	313.0	3.195	
9		0.5065	2.608	"	5	220.8	"	"	316.0	16828	9324	33.34	279.7	3.575	
10		0.300	1.548	987	5	102.7	5000	10325	150.05	7990 / 8000	8282 / 8290	29.67	289.2	3.458	
11		0.501	2.556	"	5	137.2	"	"	196.6	20300 / 20300	11250 / 11250	129.57	226.9	4.407	
12		1.505	7.766	"	4	190.9	"	"	273.6	28250 / 28250	15650 / 15650	148.9	105.1	9.515	

Plan and Diametral Section of Steelton Ring #7.



External Rad: 11·0395 Diam 22·079 Circ. 69·385
Internal " 9·8025 " 19·605 " 61·590
Mean " 10·421 " 20·842 " 65·47

External area cannot 380·4
Int: " " 301·86
Annulus " " 78·54

Depth (mean of 8 readings) 1·238 (0·54226")
Radial breadth (" " ") 1·237 (0·48868)
Gross section 1·70445
Volume 185·60
Weight in air 870·0 gm
" H_2O 758·75
Volume by weighings 111·25
Specific gravity 7·82

Edge depressed at one efflux $\frac{1}{100}$ 1·796 1·238² = 1·8989
Depression 1·237² = 1·5302 3·4291 1·852
Loss of area 0·0556
Gross cross section 1·70144 accepted section

Winding. Two secondaries 50 turns each
Primary 1st layer 338
2nd " 337 675
3rd " 338 338
1013 1013

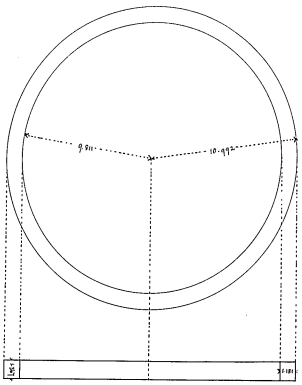
$$H = \frac{1·2566 \times 1013}{65·47} = 19·444 \text{ per cm}$$

Test of Steelton Welded Ring #7 June 12th 91.

No of Obs	Steel: a/750	Observed a/1478	Amplitude	Turns	No of Rev	Mean Rev	Phase in rad.	C. of G rad.	q	φ	L	H	μ	ρ	Secondary Turns
1	0·0963		0·07147	339	5	1·1	0	5380	1·56618	89·2	249·5	0·4834	102·3	9·775	50
2	0·13609		0·1055	"	5	1·5	"	"	2·136	114·9	67·5	0·6834	98·7	10·13	"
3	0·2217		0·1719	"	5	2·5	"	"	3·56	191·5	112·6	1·1134	101·05	9·895	"
4	0·5562		0·4312	"	5	7·7	"	"	10·965	589·7	3466	2·795	124·0	8·064	"
5	0·6048	0·0975	0·4689 0·2931	"	5	9·0	"	"	12·82	689·6	405·3	3·039 3·268	132·4 120·4	7·406 8·039	"
6		0·115	0·573	"	5	12·	"	"	17·09	919·4	540·4	3·843	140·6	7·112	"
7		0·2355	1·215	"	5	53·5	"	"	76·18	4097	2409	7·872	306·	3·268	"
8		0·3335	1·721	"	5	149·6	"	"	213·0	11460	6734	11·15	604·1	1·655	"
9		0·5615	2·897	"	5	221·6	"	"	315·6	16980	9978	18·78	531·2	1·882	"
10		0·236	1·218	1013	5	130·8	5000	10380	186·25	10,330	6,364	23·68	480·0	2·083	"
11		0·38	1·961	"	5	157·3	"	"	224·0	23,250	13,660	38·11	358·5	2·789	"
12		0·524	2·807	"	5	171·2	"	"	243·8	25,310	14,880	54·56	272·7	3·667	"
13		1·62	8·358	"	5	203·4	"	"	289·6	30,060	17,670	162·5	108·8	9·191	"

No of Obs	Source of EMF	EMF at Comp.	Intensity	q	Mean Rev	q per div	R. of q.
11	1.B.C.D 27C	1·94247	2P	$2·84·94 \times 10^{-7}$	200·1	$14·24 \times 10^{-5}$	5380

Plan and Diametral Section of Stratton Welded Ring #8 1/2



External Rad: 10.992, Diam: 21.984, Circ: 69.06
Int: " 9.811, " 19.622, " : 61.64
Mean " 10.4015 " 20.803 " : 65.36

External area covered 380.783
Internal " " 302.398
Annulus " " 78.385

Depth (mean of 8 readings) 1.367 (0.5381")
Radial breadth (" " ") 1.181 (0.4650")
Cross section 1.614

Volume ~~99.68~~ 105.3
Weight in air 808.6
" " Lap H_2O @ 20°C 704.95
Volume by weighing 103.65

Sp: gr: 7.80

Edge depressed at one spot (Dia) 1.743 1.347" : 1.806 cm
Centre depression 0.0624 1.181" : 1.3948 3.2635/ = 1.807
Loss of area 0.00141 0.4739
Mean cross section 1.5099 accepted 1.61

Winding Primary)
1st Layer 338
2nd " 337 675
3rd " 338 338
1013 1013

Secondary) Coils 50 turns each.

$H = \frac{1.2566 \times 1013}{65.36} = 19.47$ per amp

Test of Stratton Ring #8. June 12th 91.

No of Obs	Source of EMF	EMF at temp	Capacity	a	Mean Rheo	q. per div:	R. of G.
12	16 cells @ 23°C	1.4285	2 μ	2.857×10^{-7}	200.5	1.425×10^{-3}	5310

No of Obs	Sht: ×7705	Unsht ×938	Amp.	Turns	No of Mean	Mean Read	Rheo cor.	Rig cor.	q.	q	L	H	μ	f ×10⁻³	Seen here
1	0.09933		0.0769	338	5	0.9	1	5310	1.2830 ×10⁻⁴	68.2	42.4	0.499	814.9	11.77	50
2	0.13165		0.1021	"	5	1.3		"	1.853	98.4	61.12	0.663	92.2	10.85	
3	0.42447		0.3291	"	5	4.9		"	6.924	370.9	230.4	2.137	107.8	9.03	
4	0.61982	0.100	0.4798 0.5216	"	5	8.1		"	11.54	612.7	380.6	3.115 3.35	122.2 113.6	8.19 8.80	
5		0.127	0.655	"	5	13.2		"	18.81	999.	620.5	4.252	146	6.85	
6		0.170	0.877	"	5	25.75		"	36.7	1949.	1211.	5.692	212.8	4.70	
7		0.243	1.254	"	5	68.1		"	97.06	5154.	3201	8.140	393.2	2.543	
8		0.4024	2.085	"	5	150.05		"	213.8	11350	7048	13.54	520.6	1.921	
9		0.600	3.096	"	5	205.4		"	292.8	15550	9656	20.1	480.5	2.081	
10		0.588	3.035	1013	5	158.9	5800	10310	226.3	23,330	14490	57.09	245.2	4.078	
11		0.347	1.791	"	5	136.5	"	"	194.6	20060	12,460	31.87	357.3	2.8	
12		2.037	10.51	"	5	194.	"	"	276.5	28.500	17,705	201.6	86.5	1156	

Top + Bottom 2' × 6·5' = 13 sq. feet each — 26 sq. ft.
Back and front four 0·8 × 6·5 = 5·2 " " " — 10·4 " "
Sides 0·8 × 2 = 1·6 " " " " — 3·2 " "
— 39·6 " = 36,790 sq. cms.

154 × 0·18 sq = 27·16·4" say 16·5".

Data and Determination of the Winding for a large Ore Milling Magnet at Ogden Mill no 1. 11th June 91.

Information was received on the 10th June, that one of three magnets had "burned out", and the winding required to renew was asked for by Ogden. The data of the destroyed winding was wired for to Schenectady, and the following answer received.

Large magnet wound in three sections:—

Bottom section	4 layers @ 154 turns per layer.	Res: 10·8 ω	258 lbs.		
Middle	4 " " 147 " " "	10·5 ω	251 "	#13 B&S	
Top	4 " " 138 " " "	10·1 ω	241 "	0·095	
				0·147	

The magnet is 6 feet long 2 feet wide and 10 inches thick.

From this with 36·56' per lb, we have

Bottom section	616 turns	9438' = 15·32' per lb, 10·8 ω	258 lbs.	This makes the length 6·7 feet.
Middle	588 "	9178' = 15·61' " 10·5 ω	251 "	
Top	532 "	8810' = 16·56' " 10·1 ω	241 "	
	1736 "	27,420' = 15·8' " 31·4 ω	750 "	

It is said that at 30 amp: the power of the magnet was good but that by heating the current afterwards an hour would fall to 20 amp. with inferior results.

At 35 amp: the voltage would be 123. approx.

123 × 30 = 3690 Watts energy developed in magnet.

Free surface of magnet = 36790 sq: cms.

9·97 sq: cms: per watt.

Simplex: turns at continuous load 17360, at 35 = 20,300 ft. at start

The problem is therefore to give 20,000 amp: turns on steady load at 60° C. with 20 sq: cms: per watt or 15 amperes, = 11400 turns of wire = 22,400 feet. The resistance at 60° C. to be $\frac{120}{15}$ = 8 ω = 2800 feet per ohm = #5 B+S. 0·1819" covered to 0·194"

16·5 ÷ 0·194 = 85 turns per layer. = 16·147 layer = 3·2 deep.

Weight 8 ω 321·3 lbs. per ohm = 2570 lbs: @ 0·26 = $668

This wire is probably too large to handle.

Dividing into three sections each. 5·4" wide. and each 24 ω res: 11400 turns on each = 22,400' on each = 9333 feet per ohm = #12 B.W.G. 0·109" covered to 0·120". = 1145 turns per layer and 31 layers = 3·7" deep. Weight 72 × 41·41 lbs per ohm = 2982 lbs: for in all.

Cost 3000 #26 = $780.

If 20 ampire be allowed, or 15 sq. cms. per Watt.

The res: @ 60° C. 6 ω = and $\frac{21000}{20}$ = 1050 turns @ 16' = 16800'

= 2800' per ohm = #5 B+S.

Dividing into two sections each 8·125" wide and 1050 turns and 12 ω = 16800 ÷ 12 = 1400' per ohm. = #8 B+S. 0·1285" covered to 0·140"

= 58 turns per layer. = 18 layers = 2·5" deep.

24 ω @ 70 lbs per ω = 1680 lbs = $450

Winding in two parallel divisions each 8⅛" side by side.

1680 lbs. of #8 B+S. wire 0·1285" covered to 0·140", 840 lbs. in each section

Resistance of each section. 12·02 ω in multiple 6·01 ω @ 60° C.

Current at 120 volts pressure 20 & 10 in each section

58 turns per layer in each section

18 layers

1050 turns in each section 2100 turns in all.

2·5" depth of winding

15 sq: cms: of magnet surface per watt.

Analysis of Results obtained from the 8 Stretton Welded Rings of definite composition. 13th June 91.

The reluctances of these rings having been plotted for different flux densities, it is evident

1st That the quantity of Carbon present is the ruling factor in the reluctance and that the difference in reluctance between cast ordinary iron and the best Norway iron or magnetic cast steel, is mainly owing to the difference of richness in carbon.

2nd That Silicon & Manganese appear to come next in importance, of magnitude in effect

3rd That Phosphorus, and for at least as 0.1 %, appears to have least influence quantitatively.

4th That as the iron becomes magnetically more and more inferior the flux density at which the minimum reluctance is shewn diminishes.

5th That with carbon at least the quantitative influence of its presence, on the reluctance, is not simply proportional, but involves squares or higher powers.

6th That disregarding the last item, or in other words keeping the estimate (owing to insufficient data) down to a first approximation, and order, the reluctances of these rings nearly satisfies a linear relation taken from their analyses assuming that each ingredient adds a definite and simply proportional reluctance while pure iron is supposed to have none at a density of 7500.

This relation is nearly satisfied by making

1% Carbon = 2.5 millilucts
1% Silicon = 1.1 "
1% Manganese = 0.6 "
1% Phosphorus = 0.4 "
1% Sulphur = 0 "

Substituting these values in the analyses we obtain

	Fe	C.	Ph	Mn	Si.	S.	
No1.	99.513	0.13 × 2.5	+ 0.008 × 0.4	+ 0.31 × 0.6	+ 0.01 × 1.1	+ 0.029 × 0	= 0.525
" 2	99.332	0.18 × 2.5	+ 0.088 × 0.4	+ 0.39 × 0.6	+ 0.01 × 1.1	+ 0.05 × 0	= 0.605
" 3	99.165	0.33 × 2.5	+ 0.013 × 0.4	+ 0.46 × 0.6	+ 0.01 × 1.1	+ 0.024 × 0	= 1.117
" 4	98.833	0.28 × 2.5	+ 0.111 × 0.4	+ 0.12 × 0.6	+ 0.02 × 1.1	+ 0.043 × 0	= 1.145
" 5	99.36	0.15 × 2.5	+ 0.048 × 0.4	+ 0.53 × 0.6	+ 0.01 × 1.1	+ 0.013 × 0	= 0.714
" 6	98.7	1.08 × 2.5	+ 0.007 × 0.4	+ 0.19 × 0.6	+ 0.01 × 1.1	+ 0.013 × 0	= 2.828
" 7	98.165	0.39 × 2.5	+ 0.088 × 0.4	+ 0.77 × 0.6	+ 0.04 × 1.1	+ 0.047 × 0	= 1.516
" 8	98.41	0.44 × 2.5	+ 0.037 × 0.4	+ 0.82 × 0.6	+ 0.26 × 1.1	+ 0.032 × 0	= 1.893

The actual reluctances observed at 7500 were :- 0.5, 0.57, 1.05, 1.38, 0.63, 3.2, 1.6 and 1.89 millilucts.

7th On substituting these values in the analysis of Lyncrest cast steel, there is a large discrepancy, shewing that the reluctance introduced by carbon in the Stretton rings, is considerably greater than the reluctance introduced by the same quantity of Carbon in the Lyncrest ring.

In the 4 1000 feeder connections, the ring is 1" long and 1" in diam making 3·14·16 sq in. = 20·27 sq cms.
The film of solder between the two may be estimated at 0·001"
= 0·0025 cm. and allowing a conductivity of 10% copper in the solder, the resistance of one such joint would be

$$10 \times \frac{1.7 \times 0.0025}{20.27} \text{ microhms} = \frac{4.25 \times 10^{-4}}{2.027} = 2.097 \times 10^{-3} \text{ microhms}$$

at each joint and there is one such joint for every 10·5 feet of conductor or 916 such joints in each conductor of this feeder. The total resistance due to such films of solder would amount in the whole feeder to 1·92 microhms.

Measurement of the Resistance of the long Brooklyn Feeder

17th June 1891. (11)

Resistance measured by Laboratory Wheatstone Bridge, and Brooklyn Thomson Galvo. Leads at Testing House 32 feet of 100,000 c. mils = 0·0001 + 0·0032 ω. Leads at E.S. vault 2 feet of 500,000 c. mils. = 0·000004 ω

First measurement + and − conductors connected by 2' of #500 conductor in the Central Station vault. This first measurement is not considered reliable.

6 volts 100% 0·201 ω deflection −13 } shunt 100Ω. Result 0·200885
0·200 ω " +100 } Leads 0·003234
0·197605 ω
Temp: Bridge 28·5°C. of air in room 27·5°C. or simply 0·098823.

Second measurement, after cleaning contacts of leads on bridge terminals, found loop disconnected. Wired to E.S. replaced it. Wires replaced.

6 volts 999% 0·208 ω deflection +11 } shunt 1/0 Result 0·208506
0·209 ω " −25 } Leads 0·003234
0·205272
Temp: Bridge 28·5°C. or simply 0·102638

Third measurement, after E.S. had been asked to tighten up contacts

6 volts 1099% 0·229 ω deflection +20 } no shunt Result 0·20907
0·230 ω " −10 } 0·003234
0·20583
simply 0·10292

Fourth measurement, after E.S. had looped + and ± conductors

6 volts 999% 0·392 ω deflection +17 } no shunt Result 0·39780
0·393 ω " −20 } 0·003234
0·394566

Fifth measurement, after E.S. had looped − and ± conductors

6 volts 999% 0·392 ω deflection +32 } no shunt Result 0·39835
0·393 " −2 } 0·003234
0·39511

Sixth measurement after E.S. had looped + and − pressure wire

6 volts 1099% 16·03 ω = 8·015 ω each.

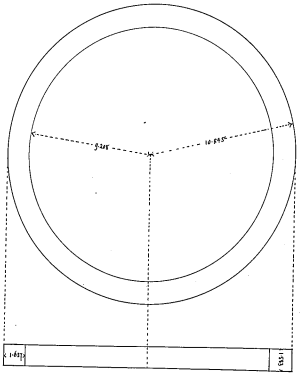
			cted for T.S.	Res per foot
Mean deduced res: of	+ and ⊖	0·205544		
	+ and ±	0·38956		
	− and ±	0·39011		
		0·98522		
		0·49261		
	+	0·10250	0·1028 ω	1·111 × 10⁻⁵
	−	0·10305	0·10335 ω	1·116 × 10⁻⁵
	±	0·28706	0·2898 ω	3·115 × 10⁻⁵

From these the res: per c. mil foot = from the + 11·11 ω
11·16 ω
10·92 ω

Supposing that being a warm day, the mean temperature of the conductors in the tube was even 30° C. the res: of 1 mil foot at that temperature = 10·52 ω (Regt.)
The conductivity of the + conductor is thus 0·9427
− " " " " 0·94225
± " " " " 0·9634

These results compare favorably with those obtained by a different method on the 24th May (see Book IV p. 159. in which the res: of the + feeder = 0·1019 ω. the difference may easily be due to the difference in temperature of the tube on the two different occasions.

Plan and Diametral Section of Ring $ & A 1/2.



External Rad: 10.845, Diam: 21.690, Circ: 68.14, Rad² = 117.61
Internal - 9.208, - 18.416, - 57.86, 84.787
Mean - 10.0265 - 20.053 - 63.00, 82.93

Annular Area 103.12

Mean Radial breadth (8 obs) 1.637 0.644146"
- Depth (8 -) 1.583 0.62314"

Volume 163.25
Cross Section 2.591
Weight in air 1261.5
- buf H_2O 1100.6
Volume by weighing 160.9
Sp. g. 7.839

Winding Secondaries 50 turns each
Primary
1st layer 310
2nd - 309 619
3rd - 310 310
929 929

$H = \frac{1.2566 \times 929}{63.0} = 18.53$

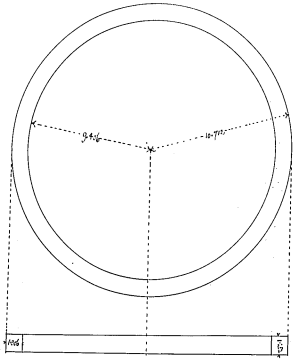
Magnetic Test of Steel Ring cast at Bethlehem (12.
marked A_6 and containing by analysis
C 0.29 Mn. 0.333 Si. 0.261
15th June 1891

A few small blowholes visible on the surface, but good metal.

No. of Obs.	Source of EMF	B.M.F. at temp.	Capacity	a	Mean Rheo	q per div.	A. of G.	
8	1 Pt. 28.4°C	1.1423	2.0	2.846×10^7	199	1.43×10^{-9}	5400	

No. of Obs.	Std. G. 27722	Obsrd. 1931	Amp.	Turns.	No. of Throws	Mean Rheo	Rheostat & Batt.	Res. of G. al.	q $\times 10^{-9}$	φ	B	H	μ	ρ $\times 10^{-3}$	Seconds hum
1	0.0919		0.0912	310	5	3.6	0	5400	5.149	278.	107.3	0.4397	213.3	4668	50
2	0.12722		0.09862	-	-	5.4	-	-	7.722	417.1	161.	0.609	264.3	3784	
3	0.20345		0.1577	-	-	9.8	-	-	14.02	757.2	292	0.974	299.7	3337	
4	0.39391		0.3054	-	-	27.4	-	-	39.19	2117	817.2	1.886	433.3	2.309	
5	0.54296	0.085	0.4221 0.4387	-	-	59.35	-	-	84.88	4585	1770	2.60 2.71	680.6	1.469	
6		0.2[illegible]	0.6245	-	-	141	-	-	201.7	10890	4203	3.984	653	1.531	
7		0.164	0.8466	-	-	198.5	-	-	284.3	15360	5927	5.229	1133.	0.883	
8		0.240	1.2385	-	-	163.4	5000	10,400	205.1	21330	8232	7.65	1075.	0.930	
9		0.297	2.049	-	-	191.	-	-	273.2	28.410	10970	12.66	866.5	1.154	
10		0.240	1.239	929	-	229	-	-	327.6	34,070	13150	22.96	572.9	1.7455	
11		0.395	2.0385	-	-	170	10,000	15,400	243.1	37.430	14450	37.77	383.4	2.608	
12		0.162	0.996	-	-	1974	-	-	282.4	43.490	16790	111.1	151.1	6.619	
13		1.955	10.09	-	-	212.1	-	-	303.4	46.730	18.040	186.9	96.5	10.36	

Plan and Diametral Section of A2 Ring 1/2.



External	Rad: 10.712	Diam: 21.424	Circ: 67.38	Rad² =	114.70
Internal	" 9.4275	" 18.815	" 59.11	" =	88.50
Mean	10.0698	20.1195	" 63.21	" =	26.20

Annular area 82.3

Radial breadth (8 rdgs) 1.306 (0.5142")
Depth (") 1.252 (0.493")
Cross section 1.635
Volume 132.4
Weight in air 797.3
" " kaolite 675.4
Volume by weighing 101.9
Sq. 7.825

Winding Secondaries 50 turns each
Primary
1st layer 310
2nd " 309
3rd " 310
929

$$H = \frac{1.2566 \times 929}{63.21} = 18.47$$

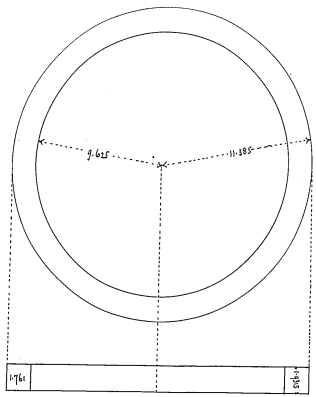
Magnetic Test of Steel Ring cast at Bethlehem Pa. (13)
A2 containing 0.31 C, 0.016 Mn, 0.114 Si. 16th June

Only a few small blow-holes visible on surface but metal much reduced to cut out holes from ring. The condition of this sample and inferior therefore to some of the others, as a casting

No. of Rk	Source of EMF		E/MF at Temp		Capacity		a		Mean Power		q/ per div.		R. of Gj	
12	B.B.@ 76		1.4234		2 ϕ		2.848×10^{-7}		194.4		1.1465×10^{-3}		53900	
No. of Rk	Std. G. k=7112	Shunt r=1438	Amps.	Turns	No. of Rk	Mean Rdg	Addtl. R. of G at		q/	φ	B	H	μ	ρ ×10⁻³	Remarks
1	0.09829		0.9746	310	5	2.3	0	5390	3.370	181.7	111.1	0.459	242.2	4.13	50
2	0.20385		0.1978	-	-	5.1	-	-	7.472	402.9	246.4	0.972	253.5	3.94	
3	0.41421		0.3212	-	-	18.25	-	-	26.74	1441.2	881.6	1.978	445.7	2.24	
4	0.60086	0.092	0.4658 0.4747	-	-	42.1	-	-	61.67	3324	2031.	2.868 2.923	708.0 695.6	1.410 1.438	
5		0.1144	0.7425	-	-	93.1	-	-	136.4	7352	4496	4.576	982.8	1.018	
6		0.1776	0.8975	-	-	113.6	-	-	166.4	8968	5483	5.527	992.3	1.009	
7		0.2413	1.2574	-	-	157.4	-	-	230.6	12430	7603	7.722	984.4	1.016	
8		0.4110	2.116	-	-	274.1	-	-	313.6	16,900	10,340	13.03	793.5	1.260	
9		0.2412	1.2419	929	-	264	-	-	386.7	20,845	12,750	23.07	552.8	1.809	
10		0.399	2.059	-	-	150.4	5000	10,390	220.3	22,890	14,000	38.03	368.1	2.717	
11		0.778	4.014	-	-	167.1	-	-	244.8	25,430	15,555	74.15	209.8	4.766	
12		2.045	10.55	-	-	191.5	-	-	280.6	29,150	17,830	191.9	92.93	10.93	

$0.31 \times 2.5 + 0.016 \times 0.6 + 0.114 \times 1.1 = 0.910$ @ 6.7500 Assumed 1.0

Bethlehem Cast steel Ring B6 Plan and Diametral Section 1/2.



External	Radius 11.385,	Diam 22.770	Circ. 71.52	Rad² 129.66	
Internal	- 9.625	- 19.250	- 60.47	92.64	
Mean	10.505	21.010	- 66.00	37.02	

Annular area 116.3

Radial breadth (8 readings) 1.761 (0.6932")
Depth (- -) 1.9315 (0.7604")
Cross section 3.401
Volume 224.5
Weight in air 1742.
- - in H_2O 1520.2
Volume by weighing 221.8
Sp. g. 7.853

Winding Secondaries 50 turns each
Primaries
1st layer 328
2nd - 327 655
3rd - 328 328
983 983

$$H = \frac{1.2566 \times 983}{66} = 18.72$$

Test of Steel (Cast) Ring from Bethlehem No # B6

(116)

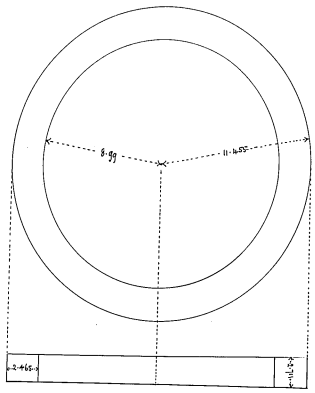
Containing C 0.126 Mn 0.347, Si. 0.195.

No. of Obs.	Source of Errs	Errs at temp.	Capacity	a	Mean thick.	q. per div.	mm. of Q.	
12	1 Pt.@ 27.6°C	1.1224	2.0 f	2.848×10^{-7}	194.4	1.1465×10^{-3}	5390 ω	

No. of Obs.	Ist. q	Obsd.	Amp.	Time	No. of Throws	Mean throw	Residual q.	Rem. of Q. obs.	q.	q	L	μ	μ	ρ.	Secondary hmm
	0.07756	0.1938												$\times 10^{-3}$	
1	0.07776		0.0758	938	5	45.8	0	5390	67.1×10³	361.7	1.964	1.1419	750	1.333	50
2	0.13372		0.1037	-	-	108.5	-	-	1594 ·	8570	2.521	1.9141	1299	0.7698	
3	0.19438		0.1507	-	-	208.5	-	-	3055 ·	16470	4.843	2.821	1717	0.5822	
4	0.82447		0.2391	-	-	191.44	5000	19390	2848 ·	29590	9.701	6.161	1412	0.708	
5	0.75355	0.115	0.5842 0.5932	-	-	86.9	25.000	30390	1273 ·	38690	11380	10.94	1040	0.962	
6		0.140	0.7234	-	-	93.7	-	-	1373 ·	41730	12.270	11.105	1105	0.905	
7		0.340	1.239	-	-	105.8	-	-	155.0	47110	13.850	23.19	597	1.675	
8		0.3953	2.057	-	-	115.5	-	-	169.2	51428	15,125	38.51	393	2.545	
9		0.775	4.000	-	-	124.5	-	-	182.9	55550	16,340	74.87	218	4.587	
10		2.050	10.58	-	6	142.1	-	-	208.1	63250	18.600	198.1	93.9	10.64	

$2.5 \times 0.126 + 0.347 \times 0.6 + 0.195 + 1.1 = 0.747$ (247500 ; 0.65" observed.

Plan and Diametral Section of Bethlehem Ring B4 1/2



Internal Rad. 8.99,	Diam. 17.98	Circ. 56.48	Rad² 80.82
External " 11.455	- 22.910	- 71.96	- 131.22
Mean - 10.2225	- 20.445	- 64.22	Diff 50.40

Annular area 158.33

Depth (8 readings)	2.711	(1.0673")
Radial breadth (- -)	2.465	(0.9703")
Gross section	6.683	
Volume	429.2	

Weight in air 1st trial	3322.6	second trial	3322.2
- - by H_2O -	2897.6	- -	2895.8
Volume by weighing	425.	- -	426.4
Sp: gr. - -	7.818	- -	7.790

Windings: Secondaries 50 turns each

Primary 1st layer 321
2nd - 320 641
3rd - 321 321
962 962

$$H = \frac{1.2566 \times 962}{64.22} = 18.82$$

Magnetic Test of Cast Steel Ring from Bethlehem marked B4. (15)

Analysis no C. 0.116 Mn. 0.003 Si: 0.030.
blowholes visible

No. of Obs:	12	Source of EMF	1 C. cell @ 25°	EMF at temp	1.4242	Capacity	2 ϕ	a	$2.814.84 \times 10^{-7}$	Means Mean	191.3	q. per div.	1.489×10^{-3}	Res. of G.	5390	

No of Obs	Ext. rad. of Ring	Ext. rad. of G.	Shunt	Amps	Turns	No. of Shunts	Mean Mean	Ri. added to G.	Ri. of G. coil	q	ϕ	b	H	μ	ρ	Secondary turns
										$\times 10^{-3}$					$\times 10^{-3}$	
1	0.03629			0.07461	321	5	15	D	5390	22.34	8204	180.1	0.468	384.7	2.599	50
2	0.13165			0.1021	"	"	26.2	"	"	39.02	2,103	314.6	0.6404	491.2	2.035	
3	0.20722			0.1553	"	"	58.3	"	"	86.82	4,680	700.2	0.9742	718.6	1.392	
4	0.407161			0.3158	"	"	153.6	5000	10,390	228.7	23,765	355.6	1.981	1795	0.5571	
5	0.461601			0.3574	"	"	63.8	25,000	30,390	95.0	28,870	4,320	2.242	1927	0.5189	
6	0.612280	0.092		0.4751	"	"	86.35	"	"	128.7	39,110	585.1	3.670	1594	0.6274	
				0.4748												
7		0.125		0.6145	"	"	113.	"	"	168.3	51,150	765.4	4.046	1892	0.5285	
8		0.169		0.872	"	"	136.4	"	"	203.2	61,760	924.0	5.470	1690	0.5917	
9		0.2425		1.252	"	"	162	"	"	241.3	73,340	1097.5	7.854	1397	0.7158	
10		0.345		1.781	"	"	182.9	"	"	272.4	82,800	1239.0	11.17	1109	0.9017	
11		0.486		2.588	"	"	199.	"	"	296.4	90,080	1348.0	15.735	856.4	1.1677	
12		0.2405		1.241	962	"	213.1	"	"	317.4	96,460	1443.0	27.178	531.2	1.8825	
13		0.473		2.441	"	"	232.8	"	"	346.7	105,400	1577.0	45.740	343.6	2.910	
14		1.975		10.19	"	"	275.2	"	"	409.9	124,600	1864.0	97.80	190.7	10.27	
15		3.40		17.55	"	"	302.0	"	"	449.7	136,700	2045.0	330.3	61.90	16.155	

2747

2268 ÷ 2748 = 1·8075

2747

1600

4348 ÷ 2748 = 1·5828

2747

3250

5998 ÷ 2748 = 2·183

2747

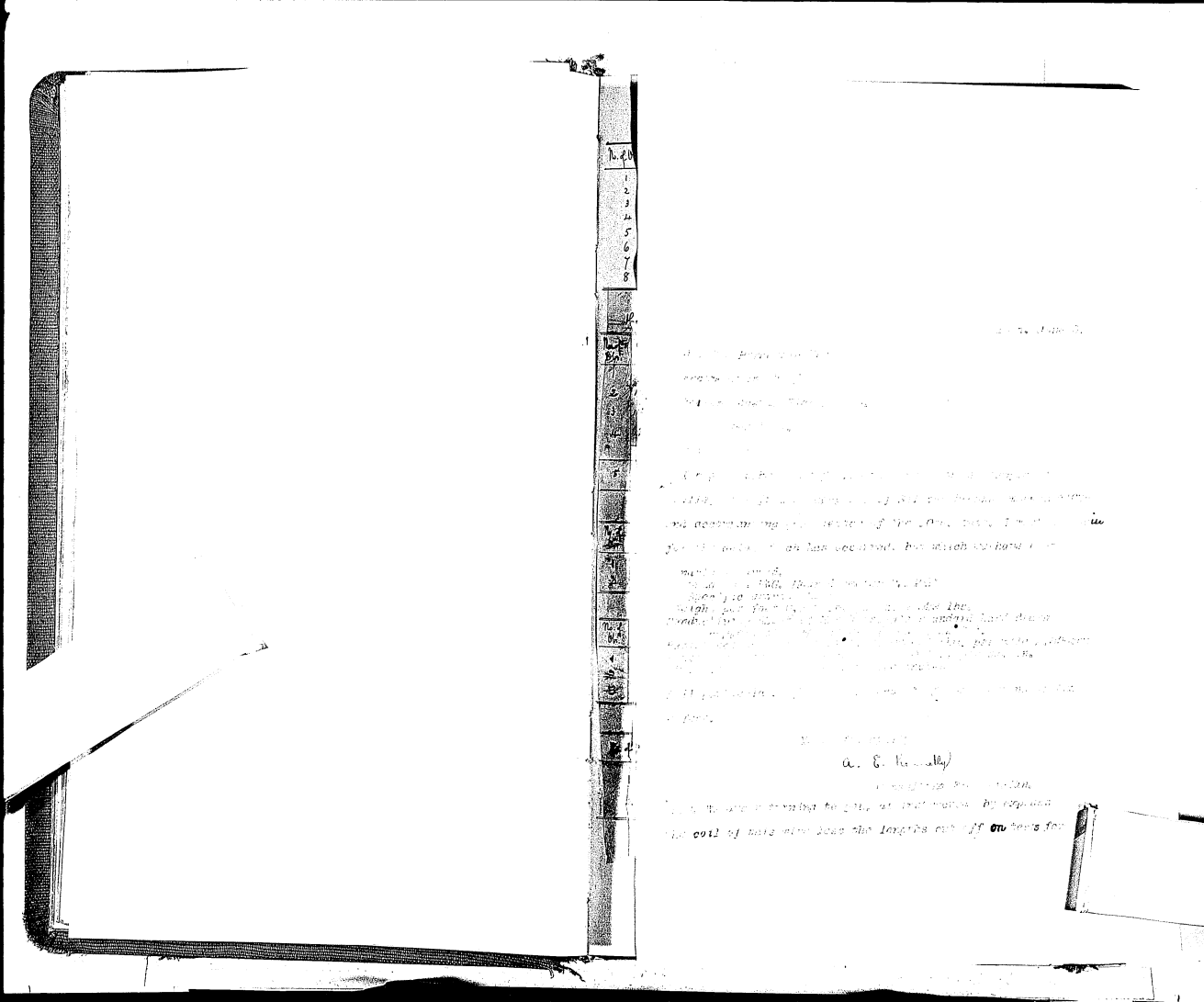
5500

8248 ÷ 2748 = 3·002

0·009778 @ 18°C. 4 × 0·021 = 0·084

0·009778 × 1·000814 = 0·009786

1598 (1 + 0·05536) = 1·73348



Test of a sample of Silicon Bronze Trolley wire manufactured by The Bridgeport Co & marked "1025"

The diameter of a 10 foot length was measured 23 times as follows:

No. of Obn.	Diam:	No. of Obn.	Diam:	No. of Obn.	Diam:	Mean	Area	D²
1	0·2099"	9	0·2096"	17	0·2096"	0·2085"	0·0341 sq.in.	0·0434672
2	0·2099	10	0·2101	18	0·2099			
3	0·2098	11	0·2099	19	0·2100	0·610 m	0·2201 sq.cm.	0·3721
4	0·2102	12	0·2103	20	0·2100			
5	0·2102	13	0·2101	21	0·2099			
6	0·2102	14	0·2101	22	0·2100			
7	0·2103	15	0·2101	23	0·2099			
8	0·2105	16	0·2103	24				

Four lengths were measured off along the floor, and compared with a standard 0·01 m as follows:—

Res: of each coil of Galvo: 2747 ω

Block 1st Unit	Length 2nd Unit	Mean	Scale	Balance	added L	Ratio	Res: of Std:	Res: of wire	Res: per mm:	Resistivity	Millimetre equivalents	Σ Cond: of wire	Mean Cond:
682·25	698·15	688·2	0·01 m.	20 ω	wire	1·00075	0·009726	0·009822	$\frac{1}{1000}$ 1·4335	4186	1735	1·41185	
1083·35	1083·25	1083·3		1600 ω	-	1·5825		2·051485	1·429	4176		1·04185	
1489·75	1489·55	1489·65		3250 ω	-	2·183		0·021362	1·4334	4191		0·41141	0·4611434
2016·25	2016·25	2016·25		5500 ω	-	3·002		0·029378	1·4357	4195		0·41136	= 0·34237 in 1 mm
				Length m	area	Σ cond: of wire	Σ cond: of Std:	Σ cond:	Σ cond:		1774		
103·5	102·5	103·5	copper rod.	273·8	0·3267	2206·32	2295	113·22					

Tensile strength by Spring dynamometer

Breaking strain	Mean	Elastic per sq. in:	Gms: per sq. in:	Kgms per sq. cm:
3000 lbs.				
3100 lbs:	3050 lbs:	67340	30545 × 10²	4735

Ductility. Twisted in lathe, one end free.

Number of twists in 6"	Mean	Number of twists in 12".
38		
37	35·3	70·6
31		

Specific gravity

No.	Weight of sample in air	Weight in water	Volume	Sp. g.	Mean	Weight per c.c.	
	12·081	10·733	1·348	8·962	8·959	2·618	
	12·9765	11·51	1·44665	8·956			

Weight of 300 cms. of the wire 7718·5 gms

" 1 " " . . 25·95 - Sp.g. 8·88. 2·618

" 30·48 " " - . 787·910 - 0·17444 lbs. 79·81 gms 0·1760 lbs.

" 1609·33 " " . . 4147·7 kgms. 9209·8 lbs. 4221·14 9342·

Res: per foot @ 22° C. 0·0004367 ω

" mile - - 2·306

Test of the Walker Recording Ammeter. contd from M. 162.

The main circuit of the instrument is a solenoid, and a magnet relay. The resistance of the solenoid is 0.020 ω
" " " relay magnet 0.036 ω
" total " both 0.056 ω

The passage of a current through the main circuit sufficient to light up one lamp, closes the relay magnet, and passes a current from the mains through a local circuit consisting of a 120-volt lamp, and one or both of two electromagnets.

The first electromagnet has a resistance of 17.4 ω and releases the catch on the escapement, allowing the clockwork to be set in motion. The action of the clockwork breaks a contact at periodic intervals and thus throws the second electromagnet into the local circuit. This by attracting its keeper winds up the driving or mainspring. This winding electromagnet has a resistance of 1.25 ω.

The average current passing through the instrument in the local circuit, during the working hours of the meter is 1.84 amp.

The total delivery through the meter from the 3rd to the 16th June was recorded on the three standard meters as follows:—

No. of Obs.	Weight 3rd June, 91	Weight 16th June, 91	Gain	Loss	Mean Gain	Meter	Multiplying factor	Calculated Gain	Actual Mean Gain	Ampère-hours
1	44·692	45·2475	0·5555		0·5581	#1	10120	5645	5628 gm	4599
2	47·4815	46·9208		0·5607						
3	46·747	47·310	0·563		0·5533	#2	10120	5607		
4	44·3255	43·782		0·5435						
5	47·535	47·1217	0·38	0·4133	0·4188	#3	13741	5755		
6	46·693	47·1175	0·4245							

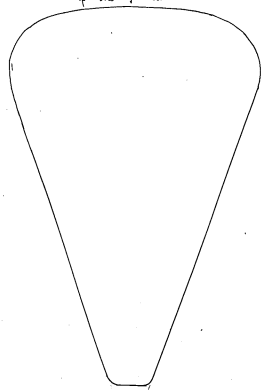
Measurements of the current strengths required to bring the marking slot on the ammeter pointer up to the successive load line holes were taken as follows:—

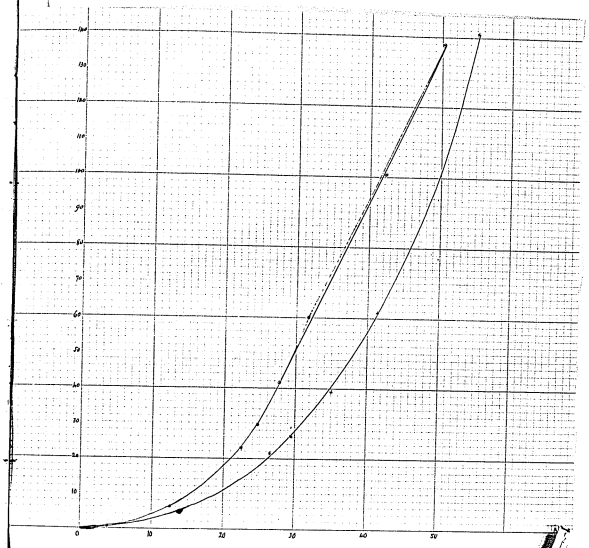
No. of Obs.	Blank	Amp.	Load hole	Amp. for hole	Δ amp.	No. of hole	Blank	Amp.	Load hole	Amp. for hole	Δ amp.
1	0·416	2·147	1	2·147	2·147	1	0·402	2·074	1	2·074	2·074
2	0·840	4·334	2	2·167	2·187	2	0·776	4·004	2	2·002	1·930
3	1·274	6·573	3	2·191	2·239	3	1·160	5·985	3	1·995	1·981
4	1·660	8·564	4	2·141	1·991	4	1·536	7·924	4	1·981	1·939
5	2·060	10·63	5	2·126	2·066	5	1·960	10·112	5	2·022	2·188
6	2·460	12·695	6	2·116	2·065	6	2·300	11·87	6	1·978	1·758
7	2·760	14·264	7	2·034	1·569	7	2·650	13·67	7	1·953	1·80
8	3·150	16·26	8	2·033	2·02	8	3·030	15·64	8	1·955	1·97
9	3·450	17·805	9	1·978	1·545	9	3·450	17·805	9	1·978	2·165

Three successive planimeter measurements of the photographic diagram gave 28·10, 28·25, 28·14 } Sq. in. mean 28·16 sq. in. = 450·5 amp. hrs.
The deficit of 9·4 amp. hrs 2·0 % short.

Energy in main ckt 0.014 to 18·2 Watts according to load
" local " 37 " during all load.
Maximum loss 55·2 Watts in both circuits
Rise of temp within meter 35° C. at full load (28° to 63° C observed).

Full-sized plane projection of one fan blade.





Measurement of the Power absorbed in driving a Brotherhood Wheels 6 bladed fan. 19th June 1891

This fan has six blades and weighs 362 gms. Its extreme diameter is 12" (30.5). The maximum breadth of each blade is 9.2. Each blade makes about 20° with the axis normal plane and is slightly curved. Material brass 0.02" thick. It was mounted in bearings and driven by a Parnell ½ H.P. motor with following results.

Balance	Moment	Observed speed	Ratio of speeds	Speed of fan	Moment $\times 61644$	Moment from gas $\times 10^4$	Revs per sec	Energy	Ratio of speeds	Ratio of energy		
50@-13	-650	0	7.93	0	-40057×10^4	0	0					
@-7	-350	-		228.	-2.158	1.849	3.8	0.7026	8.306			
- 3	-150	94		745.4	0.9246	4.993	12.42	6.926	1	1		
50@+20	+1000	170		1348.	6.1644	10.171	22.47	22.85	1.81	3.73		
50@16 100@8	+1300	188		1491.	5.0114	12.021	24.85	29.87	2.001	4.876		
50@18.5 100@10	+1775	210		1665.	10.94	14.947	27.75	41.47	2.235	6.77		
50@9 100@22	+2450	238		1887.	15.10	19.107	31.45	60.1	2.535	9.81		
50@11.5 100@20	+3575	320		2538.	19.73	23.737	42.25	100.3	3.402	16.37		
50@27 150@25	+3750	380		3014.	23.143	27.437	50.24	137.85	4.046	22.51		

When the fan was taken off the shaft the friction of the shaft in the bearings amounted to about 50 @ 10 or a moment of 500 at the highest speed. The projection of one blade on a plane is shewn on the opposite page. The vertical angle is 140°. The surface is 12.75 sq.in. = 82.2 sq.cm. and the curvature of the blade is one foot in diameter.

The area of the circle occupied by the revolving fan is 730 sq.cm.

Three alternate blades were removed from the fan and the power test repeated

No.	Balance	Moment	Observed Speed of shaft	Ratio of speeds	Speed of fan	Moment $\times 61644$	Moment from gas $\times 10^4$	Revs per second	Energy Watts	Ratio of speeds	Ratio of energy
1	50@0	0	0	7.93			$\times 10^4$				
2	50@4	200	102		808.8	1233×10^4	1.233	13.48	166		
3	50@8.5	1325	200		1586.	9.166	9.166	26.43	21.89		
4	50@16.5 100@10	1575	224		1776.	9.709	9.709	29.6	28.74		
5	50@17 100@18	1835	265		2102.	11.31	11.31	35.0	39.58		
6	50@18.5 100@28	2425	312		2474	14.98	14.95	41.23	61.78		
7	50@10.5 100@20	2525	376		2952	15.57	15.57	49.7	77.4		
8	50@15 200@15	3750	416		3299	25.65	25.65	55.0	141.1		

Inductance of the Edison Alternator 20th June 91

Field off	the alternator	2.205 ω	1000/ω	3.258	= 7.165 h
-	on (11.81) - -	2.205 ω	-	3.10	= 6.834 h

c_1	c_2	c_3	
r	0	r	$= e$
0	ρ	$-r$	$= \varepsilon$
1	-1	-1	$= 0$

$$\therefore c_1 = \frac{e(\rho+\nu) + \varepsilon\nu}{r\rho + \nu(r+\rho)}$$

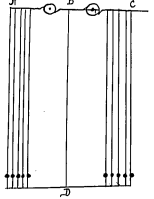
$$c_2 = \frac{\varepsilon(r+\nu) + e\nu}{r\rho + \nu(r+\rho)}$$

$$c_3 = \frac{e\rho - \varepsilon r}{r\rho + \nu(r+\rho)}$$

When as in this instance $e = \varepsilon$

$$c_1 = \frac{e(\rho+2\nu)}{r\rho + \nu(r+\rho)} \qquad c_2 = \frac{e(r+2\nu)}{r\rho + \nu(r+\rho)} \qquad c_3 = \frac{e(\rho-r)}{r\rho + \nu(r+\rho)}$$

Problem solved for Mr Jenks 21st June 91. (19)



Two dynamos of 0.025 ω armature resistance each are separately excited to equal emf such that ten lamps each having 5 ω resistance may be brought to a pressure of 50 volts when the circuits are closed as shewn. The resistances of each of the lamp wires AD, CD, being 0.5 ω, and the neutral wire BD 1.0 ω. This EMF having been reached in the armatures is permanently sustained. It is required to find the flow and pressures in the different conductors under the following successive conditions —

1st	all	5	AD	lamps	lit	and	all	5	CD	lamps	lit	
or	-	-	-	-	-	-	only	4	-	-	-	
(3)	-	-	-	-	-	-	-	3	-	-	-	
(4)	-	-	-	-	-	-	-	-	-	-	-	
(5)	-	-	-	-	-	-	-	2	-	-	-	
(6)	Only	4	-	-	-	-	-	4	-	-	-	
(7)	-	-	-	-	-	-	-	3	-	-	-	
(8)	-	-	-	-	-	-	-	2	-	-	-	
(9)	-	-	-	-	-	-	-	1	-	-	-	
(10)	-	3	-	-	-	-	-	3	-	-	-	
(11)	-	-	-	-	-	-	-	2	-	-	-	
(12)	-	-	-	-	-	-	-	1	-	-	-	
(13)	-	2	-	-	-	-	-	2	-	-	-	
(14)	-	1	-	-	-	-	-	1	-	-	-	
15	-	1	-	-	-	-	-	1	-	-	-	

The solution obtained is as follows —

No. of Case	Current in AB.	Current in BC.	Current in BA.	Current in each AD lamp	Current in each CD lamp	Pressure at each AD lamp	Pressure at each CD lamp	Effect of pressure on AD lamp	Excess of pressure on CD lamp
1	50	50	0	10	10	50	50	0	0
2	46.64	42.89	3.77	9.328	10.72	46.64	53.6	− 3.36	+ 3.6
3	42.78	34.65	8.13	8.556	11.55	42.78	57.75	− 7.22	+ 7.75
4	38.26	25.614	13.22	7.652	12.52	38.26	62.6	− 11.74	+ 12.6
5	32.9	13.662	19.24	6.58	13.66	32.9	68.3	− 17.1	+ 18.3
6	40.18	40.18	0	10.045	10.045	50.23	50.23	+ 0.23	+ 0.23
7	37.04	32.64	4.4	9.26	10.88	46.3	54.4	− 3.7	+ 4.4
8	33.32	23.73	9.6	8.33	11.865	41.65	59.33	− 8.35	+ 9.33
9	28.88	13.05	15.83	7.22	13.05	36.1	65.25	− 13.9	+ 15.25
10	30.27	30.27	0	10.09	10.09	50.45	50.45	+ 0.45	+ 0.45
11	27.144	22.17	5.27	9.15	11.09	45.75	55.45	− 4.25	+ 5.45
12	23.98	12.30	11.68	7.99	12.3	39.95	61.5	− 10.05	+ 11.5
13	20.27	20.27	0	10.135	10.135	50.68	50.68	+ 0.68	+ 0.68
14	17.91	11.37	6.514	8.96	11.37	44.8	56.85	− 5.2	+ 6.85
15	10.18	10.18	0	10.18	10.18	50.9	50.9	+ 0.9	+ 0.9

2+2
4+5
6+7 × 0.021 = 0.1147

65.2m
2758
9382 2758/9382 × 0.100114

266 − 18 = 7.6 × 0.021 = 0.1596 0.009771 × 1.0016 = 0.009794

2758 + 10/2758 = 1.0036

2767 + 9/2758 = 2667/2758 = 1.0035

2758 + 52/2758 = 2810/2758 = 1.0190

2758 + 147/2758 = 2905/2758 = 1.0534

2758 + 1015/2758 = 3773/2758 = 1.3681

2758 + 1045/2758 = 3803/2758 =

1.0144 × 24 = 1.056 ratio 1.01056 0.9896 0.0044 × 24 = 0.176 ratio 1.0176 0.99744
× 30 = 1.32 " 1.0132 0.9869 " × 10 = 0.044 " 1.00744 0.9956
× 40 = 1.76 " 1.0176 0.9824 × 20 = 0.88 " 1.0088 0.9912

Test of the Ceiling Fan (Diehl) received from the Edison Gen. El. Co.

23rd June 91.

After a few minutes operation, the following readings were taken.

Test No.	Condition of motor	Efficiency	Volts:	Brush:	Amp.	Energy	Calculated Counter emf.	Mechanical energy absorbed.	R.p.m.	R.p.s.	Pharoah meter
1	Held	0	125	0.322	1.661	207.6			0		75.2
2	Running normally	12.3%	126	0.295	1.522	191.8	15.5	23.6	12.2	2033	
3	Fan removed running light	56.9%	126	0.140	0.722	91.0	71.67	65.75	600 est	10	

According to a letter of the 10th June from the Gen. Mgr. of the Light Power Dept: N.Y. this fan is series wound with 36.5 m of # 22 B&S wire on the field and 33 m #22 wire on the armature = 69.5 m in all.

Establishment of the Resistances of some Standard Strips for use in trolley wire and other tests.

With the Boynton Trolley wire layed along the floor, compared its res. with that of the Std 0.01 Ω, and them compared the new strips with lengths of trolley wire.

Test No.	Res: measured	compared with	Res for balance	added Ω	Res of Std at temp.	Ratio	Res: measured	Temp of coil	Res of wire per cm.	Temp of air	Temp of strip	Res: @ 0°C	Res: @ 20°C
									Log. m				
1	2 Millems: Trolley wire	0.1 Ω	65.2m	0.01Ω	0.100011	0.2911	0.029035	24.2°C.	1.142270	20°C.			
2	677.5	0.01	10	wire	0.009792	1.0036	0.009829	25.6°C.	1.1451×10⁻⁵				
3	A bf.	335.6m Trolley wire	0	0	0.0028869	1.	0.0028869	24°C.			24°C.	0.0028757	0.0028857
4	A bottom	"	90	strips	"	1.0035	0.0028681	24°C			"	0.0028029	0.0028868
5	B bf.	677.5	52	"	0.009829	1.019	0.010016	24°C			30°C.	0.009886	0.009972
6	B bottom	"	147	"	"	1.017	0.009998	24°C.			30°C.	0.009961	0.009947
7	C bf.	2811 cm	1045	"	0.029611	1.3681	0.040530	24°C.			40°C	0.039955	0.040016
8	C bottom	"	1045	"	0.029611	1.3790	0.040834	24°C			40°C.	0.040012	0.040078

Particulars of some experimental Carbon filaments made by Mr Edison

26th June 91

Length 16

Diam: 0.0122 = 1.22×10^{-2}

Area 1.169×10^{-4}

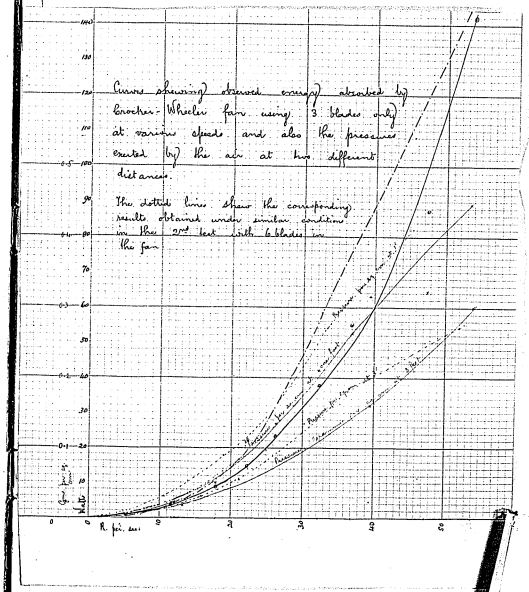
Mass 3.2×10^{-3} = 2.0×10^{-4} per cm.

Resistance cold approximately

Resistivity cold

Sp. g. 1.78

Surface tension negative in air and water. A straight piece 16.5 long will float either horizontally or vertically until completely submerged.



Curves showing Power absorbed by Crocker-Wheeler fan using 3 blades only at various speeds and also the pressure created by the air at two different distances.

The dotted lines show the corresponding results obtained under similar conditions in the 2nd test with 6 blades in the fan.

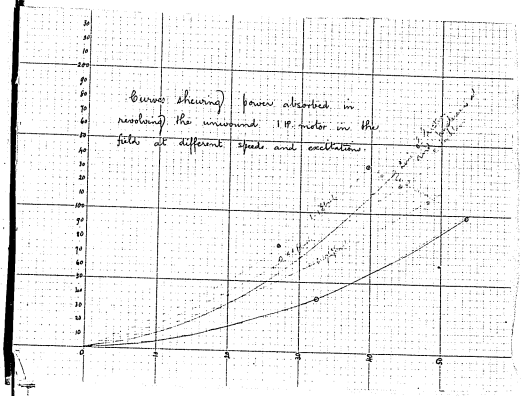
Test of the 3-bladed fan already described on page 18.
24th June 31.

To measure the pressure of wind produced at varying distances from the fan, a sheet of tinned iron weighing 4·36·5 gms and measuring 35·5 wide 38·7 high and 0·0245 (·018") thick suspended by wire from the top edge 1·3 long was allowed to hang vertically in front of the fan, whose axis was normal to the plate and not passed through its centre of figure. Where the fan was driven at different speed, the amount of power required to drive it and also the angle of deviation of the fan were noted.

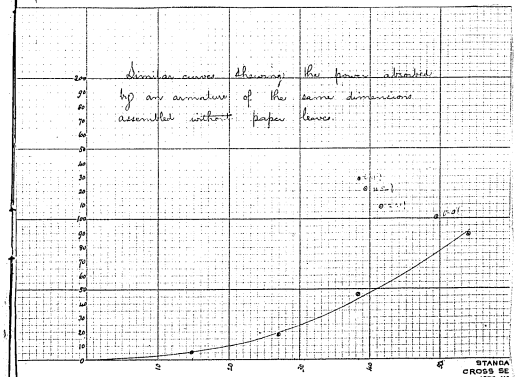
Test No.	Speed of fan rpm	Speed of fan rps.	Balance	Moment	Gibbs Moment	Energy watts	deflection	tan 12·75	θ	cos θ	effective area	effective pressure	pressure per unit area	Dists of plate
1	336	5·6	5203	150	0·924 x10	0·518	0·8 dia				1374	0		30·5 (12")
2	697	11·62	10·2	5·10	3·144	3·654	0·8 dia	0·06275	3°·35'	0·9980	1371	27·4	0·02	"
3	1078	17·97	16	800	4·931	8·962	2·0	0·1569	8°·55'	0·9879	1358	68·5	0·050	"
4	1331	22·2	21·5	1075	6·626	14·71	3·1	0·2432	13°·26'	0·9730	1337	106·2	0·109	"
5	1584	26·4	29	1450	8·936	23·60	5·0	0·3922	21°·35'	0·9309	1279	171·3	0·134	"
6	1933	32·2	500 @ 3·2 / 100 @ 10	1960	12·08	38·90	7·3	0·5727	29°·48'	0·8677	1193	250·1	0·2096	"
7	2218	36·97	500 @ 3·2 / 100 @ 15	2410	14·86	54·95	8·7	0·6824	34°·19	0·8293	1135	297·9	0·2625	"
8	2852	47·53	50 @ 2·97 / 100 @ 25	2985	18·40	87·46	10·1	0·7922	38°·23'	0·7837	1077	345·8	0·3212	"
9	3232	53·87	50 @ 3·56 / 100 @ 35	4275	26·35	142·0	12·7	0·996	44°·53'	0·7055	973·6	431·7	0·44465	"
10	2376	39·6	50 @ 3·72 / 100 @ 20	2360	14·55	57·62	5·8	0·4553	24°·23'	0·9102	1251	198·6	0·1587	91·5 (36")
11	1901	31·7	50 @ 2·8 / 100 @ 10	1000	12·33	39·08	4·4	0·3465	19°·2'	0·9456	1299	150·6	0·1160	"
12	792	13·2	100 @ 1·5	525	3·237	4·272	0·75	0·0588	3°·21'	0·99823	1372	25·67	0·0187	"
13	3232	53·87	50 @ 3·7 / 100 @ 35	3850	23·73	127·9	9·7	0·761	37°·16'	0·79583	1093	332·2	0·304	"

This test was repeated with the three streamlined blades replaced, as follows

Test No.	Speed of fan rpm	Speed of fan rps.	Balance	Moment	Gibbs Moment	Energy watts	deflection	tan 12·75	θ	cos θ	effective area	effective pressure	pressure per unit area	Dists of plate
1	444	7·4	50 @ 7·5	375	2·312 x10⁶	1·449	0·5	0·0392	2°·15'	0·9992	1373	17·12	0·0125	12·7 30·5
2	642	10·7	" "	"	"	2·473	1·2	0·0941	5°·23'	0·9956	1368	41·09	0·030	
3	840	14·	" 13	675	4·162	5·826	2·1	0·1647	9°·21'	0·9867	1356	71·88	0·053	
4	1125	18·75	" 23·2	1160	7·15	13·41	3·5	0·2745	15°·21'	0·9643	1325	119·9	0·0905	
5	1314	21·9	100 @ 5·2 / 100 @ 20	1290	7·952	17·62	4·1	0·3215	17°·49'	0·9520	1308	140·4	0·1073	
6	1711	28·5	50 @ 6 / 100 @ 25	2300	14·18	44·02	6·7	0·5258	27°·48'	0·8853	1217	229·4	0·1895	
7	1964	32·7	100 @ 3·7 / 100 @ 25	2900	17·88	58·47	8·7	0·6822	34°·18'	0·8261	1135	298·0	0·2625	
8	2732	45·5	100 @ 3·7 / 100 @ 35	3850	23·74	108·0	12·0	0·9410	43°·15'	0·7281	1001	410·8	0·410	
9	3244	54·9	50 @ 5·5 / 100 @ 35 / 100 @ 40	4350	26·82	147·3	12·7	0·9958	44°·53'	0·7085	973·4	434·8	0·4465	
10	1267	21·1	50 @ 7·5	1175	7·092	19·15	2·2	0·1725	9°·47'	0·9855	1358	75·3	0·0552	36"
11	1585	25·	100 @ 4·7 / 100 @ 10	2000	12·33	30·95	2·7	0·2380	16°·35'	0·9584	1317	130·1	0·0987	
12	1806	30·1	100 @ 6·3 / 100 @ 15	2600	16·03	48·25	5·0	0·3921	21°·25'	0·9309	1279	171·1	0·1337	
13	2122	35·4	100 @ 8·2 / 100 @ 20	3410	21·02	71·42	5·9	0·4627	24°·50'	0·9075	1247	222·	0·162	
14	2376	39·6	100 @ 10 / 100 @ 15 / 100 @ 20	4050	24·97	98·85	7·5	0·5882	30°·28'	0·8619	11814	254·7	0·2169	
15	3168	52·8	100 @ 3 / 100 @ 25 / 100 @ 30	4600	28·35	149·7	9·0	0·706	35°·14'	0·8148	1122·5	305·2	0·2745	



Curves showing power absorbed in revolving the unwound 1 H.P. motor in the field at different speeds and excitation.



Similar curves showing the power absorbed by an armature of the same dimensions assembled without paper liners.

Test of power required to drive the Edison 1 HP. motor with and without field, before winding the armatures. 25th June 91.

This machine whose original determination appears in Book IV. p. 131 weighs 102 lbs. without commutator, brushes, or armature windings. It was driven by the Perret ¼ HP. HP. motor with different Brush. and following results.

No. of Obs.	Revs. of motor per min.	Belts	Balance	Moment	Gibbs Moment	Power	Watts per sec.	Oltaic	Amp.	MMS 5974	Power due to Field	Weight of Iron	Weight of Iron Body	Volume
1	1655 / 1780	27.	2 at 0·15 / 2 at 0·31	4550	2805	70·74	2·805	1·130	5·893	3519		13 lbs 6 oz		
2	1695 / 1815	27	"	"	"	75·74	-	0·915	4·771	2849		6 lbs 9 oz	4324	555 c.c.
3	1780 / 1890	26·3	2 at 0·15 / 2 at 0·34	3710	22·87	60·15	2·287	0·44	2·294	1370				
4	1901 / 1808	31·3	2 at 0·15 / 2 at 0·34	3210	19·79	61·9	1·979	0·195	1·017	607				
5	1810 / 1940	32·3	50 at 38·2	1910	11·77	38·0	1·177	0	0					
6	2276 / 2360	29·6	2 at 0·25 / 50 at 7	5750	33·60	133·1	3·36	1·06	5·527	3300				
7	1740 / 1800	53·1	2 at 0·11	3000	14·50	98·6	1·85	0	0					
8	2186 / 2136	36·0	50 at 13	1565	9·666	34·7	0·965	0	0			14 lbs. 2 oz		
9	2673 / 2698	41·5	2 at 0·10 / 2 at 0·40	4775	30·67	127·3	3·067	1·060	5·553	3304		6 lbs 9 oz	4324	555 c.c.
10	2696 / 2630	44·0	2 at 0·20 / 50 at 8·6	6435	27·28	120·0	2·728	0·462	2·409	1438				
11	2463 / 2570	48·0	2 at 0·10 / 50 at 14	3700	32·81	109·5	2·281	0·192	0·949	567				
12	3200	53·3	50 at 40	2000	12·33	65·72	1·213	0	0					
										4678 mms				

11 lbs. of iron : 4989 say 5000 grm = 637·7 c.c. and at 15000 ergs per cycle = $9·55 \times 10^4$ ergs per rev. = 0·955 joule per rev.

There are about 210 plates in arm. 1+2 of thickness 0·00178 = 0·007" interleaved with paper 0·001".

Armature #3 was next tested in the same way. It contains 250 plates of the same thickness and no paper. Each plate is painted with shellac varnish as it is put in position, afterwards heated in the oven, and the whole armature immediately pressed. The outside plates are about ⅛".

Weight of #3 armature 14 lbs 13 oz = 6720 grm

increasing the probable weight of iron from 4324 to 4644 or 7·4 %
" " " 210 " 250 " 19·1 % } say 15%.
" " " 0·007 " 0·008 " 14·2 %

No. of Obs.	Revs. of motor per min.	Belts	Balance	Moment	Gibbs Moment	Power	Watts per sec.	Oltaic	Amp.	MMS						Rev. cords
1	837	14·8	50 at 12	600	7·6 grm c	5·474	13·7	0								112
2	1605	26·7	" 20 at	1040	6·410	17·18	0·641	0								203
3	1585	25·1	50 " 12	1490	12·87	1·510	0·581	0								190
3a	2300	38·3	" 1900		12·82	1·502										
4	2281 / 2340	38·2	50 at 8·2 / 2 at 0·25	5440	33·54	123·1	3·354	1·32	6·91	4067						288
5	1328 / 2360	29·1	2 at 0·25	5000	30·83	180·9	3·083	0·88	4·541	2712						294
6	2467 / 2570	41·5	50 at 5 / 2 at 0·20 / 2 at 0·15	4250	26·20	108·7	2·62	0·428	2·209	1319						314
7	2478 / 2660	49·3	50 at 4 / 2 at 0·15 / 2 at 0·15	3300	20·34	100·3	2·03	0·174	0·898	536						376
8	3240	54·0	50 at 3·5 / 2 at 0·15	2675	16·49	89·0	1·649	0·082	0·423	253						452
9																
10																

$\frac{26}{13}$

$8 \times 0.021 = 0.168$

$0.009798 \times 1.00168 = 0.009814$

$\frac{26}{13} \times 0.204 = 0.204$

$0.009972 \times 1.020204 = 0.009995$

2773.

1764

1330 / 2775.

$1634 \left(1 + 26 \times 0.003388\right)$

$= 1634 \left(1 + 0.08093\right)$

$= 1634 \times 1.1009$

$= 1799$

2773

1848

3121 / 2775

2773

2301

4974 / 2775

2773

1867

4640 / 2775.

The
Re d

No. of Wire	Di
1	0
2	0
3	0.
4	0

For

No. of Wire	Length in Ft.
1	1104.5
2	760.8
3	374.7
4	1016
5	1104.5
	2

Te
Wire
D
1st
2nd

Sp

Dy. lbs.	Weight in Air
1	9.4
2	10.3

2

Specific gravity [illegible]
Weight per foot [illegible] Ins. variation [illegible] Ins.
Conductivity 41.5 % of Matthiessen's standard hard drawn copper at temperature [illegible] Fahr.
Resistance per foot at [illegible] Ohms with [illegible] Ins.
Tensile strength 2500 lbs. of [illegible] Ins. diameter [illegible]
Ductility [illegible] twists in [illegible] Ins.
Full particulars of test on receipt of instructions to that effect.

Yours [illegible]

Test of a Sample of Trolley Wire for the Engineering Department. 25th June 91.

The length of this sample of Silicon-bronze trolley wire was about 50'. Its diam.r was observed at 3 feet intervals as follows:—

No. of Obs.	Diam.	No. of Obs.	Diam.	No. of Obs.	Diam.	Mean Diam.	Mean area.	Diam.r			
1	0.2400	5	0.2401	9	0.2401	0.24008	0.0452288	0.057615			
2	0.2400	6	0.2401	10	0.2400						
3	0.2400	7	0.2401	11	0.2402	0.6097	0.29199	0.37172			
4	0.2398	8	0.2400	12	0.2402						
				13	0.2403	0.057615					
						0.37172					

Four lengths were measured off along the floor as follows:—

Wt. of	Length 1st Time	Length 2nd Time	Mean Length	Compared with	Temp.r of Air	Res.n of Std. & Coil	Res.n for balance	added L	Res.n of wire	Res.n of wire per mile	Resistivity	Mean Resistivity	Resistivity of hard drawn Cu.	Mean Cond.r
1	1104.5	1104.75	1104.63	strip 0.01 Std.	26°C.	0.099997	1767 -	holly wire	0.01632	1.47888	4.304	4.320	1.799	41.574%
2	760.8	760.95	760.88	"			358 -	"	0.011280	1.4880 -	4.330			"
3	374.7	374.65	374.68	"			2201	strip	0.005577	1.489 -	4.347			"
4	101.5	101.45	101.48	Coffin wire	30°C.		0	"	0					"
5	1104.5	1104.75	1104.63	0.01 Std.	26°C.	0.099994	1767	holly wire	0.01637	1.483 -	4.330			"
			273.8 0.3347	244 Temp.r left	25°C.									40.55%

Tensile strength — Two trials

Wire broke at 3500 lbs. pull in each case. = 77,320 lbs. per sq. in.

Ductility = Twisted in lathe, one end free to slide.

1st sample:— 30 twists in 6" or 60 per foot

2nd " 39 " " 6" " 66 " " Mean 63 twists in 12".

Specific gravity =

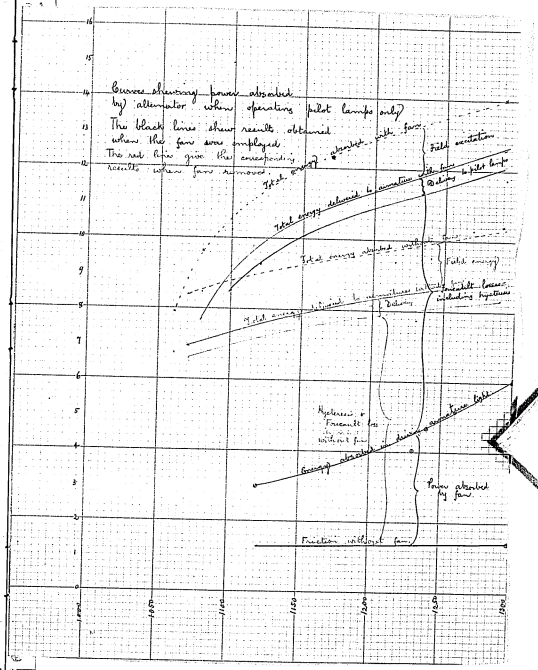
No.	Weight in air	Weight in water	Temp.r Water	Loss of weight	Sp. g.	Mean. per 1 cub. cm.	Weight per foot	Weight per mile	Mean Sp. g.	Mean Weight per cub. cm.	Mean Weight per foot	Mean Weight per mile		
1	462	8.3435	27°C.	1.0327	8.975									
2	1233	9.1716		1.1517	8.964				8.970	2.619	79.84	142,600		
											0.17594	929.40		

250 cms. of the wire weighed 654.8 grms. = 2.592

Ohms per cm. at 26°C. 1.483×10^{-5} @ 22°C. 1.460

" " foot " 0.0004520 " 0.0004445

" " mile " 2.3860 " 2.3494


Curves showing power absorbed by alternator when operating (pilot lamps only)
The black lines show results obtained when the fans were employed
The red lines give the corresponding results when fans removed
Total energy absorbed by alternator
Total energy absorbed by alternator
Total energy absorbed by alternator
Delivery
Hysteresis + Foucault's loss without fans
Energy absorbed by alternator
Power absorbed by fans
Friction without fans
1200
1150
1100
1050
1000
950
900

Tests of Alternator under varied running conditions 26th to 27th June

The alternator was operated, with 12 - 120 volt lamps in series otherwise without load. It had its fans attached. Full out 5.75. Hot 6.15

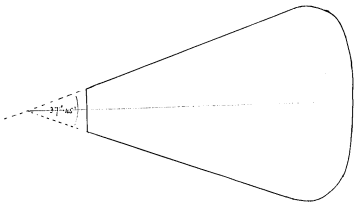
Volts at brushes	Volts at mains	Amps thro' mains	Energy in mains Kw.	C'ency Kw.	Calculated Energy absorbed by armature	Speed of armature	Fan sec	Speed of alternator r.p.m.	H.P.	Volts on field	Amps in field	Energy in field	Total Energy supplied to alternator Kw.	Calculated Efficiency	Efficiency Obtained		
120	120	12	1.44	-	0	1360	22.7	0	0	0	0	0	0				With fans
118	118	5.2	6.136	0.03	4.7	1268	21.1	12,140	20.7	"	-	-	4.7				
124	124	5.3	6.572	"	5.13			1260	21.	-	-	-	5.13				
127	127	5.9	7.492	0.07	6.0			1306	21.8	-	-	-	6.0				
113	113	4.9	5.537	0.03	4.1			1230	20.5	-	-	-	4.1				
106.5	106.5	4.2	4.472	-	3.03			1120	18.6	-	-	-	3.03				
103.5	103.5	8.0	8.28	0.07	6.77			1064	17.7	82	14.26	1.17	7.94	900			
113.5	113.5	8.8	10.0	0.09	8.47			1080	18.0	"	-	-	9.64	950			
122.0	122.0	9.7	11.83	0.12	10.27			1290	21.5				10.44	1100			
121.0	121.0	11.1	13.43	0.14	11.75			"	"	92	15.5	1.44	13.2	1200			
120.0	120.0	12.5	15.36	0.20	15.16			-	-	92	15.5	1.44	16.6	"	after 2 hours		

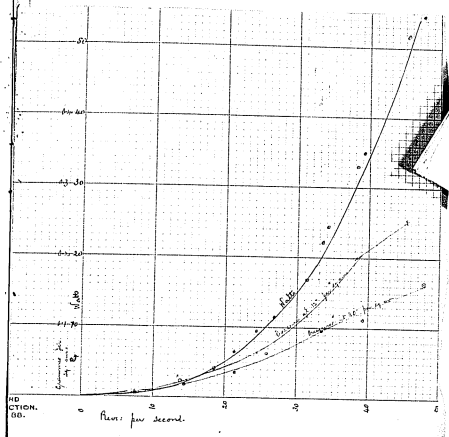
The armature temp. after stopping was 190° F air 105° F Rise of 85° F
- field - - - 128° F - 23°

Volts at brushes	Volts at mains	Amps thro' mains	Energy in mains Kw.	C'ency Kw.	Calculated Energy absorbed by armature	Speed of armature	Fan sec	Speed of alternator r.p.m.	H.P.	Volts on field	Amps in field	Energy in field	Total Energy supplied to alternator	Calculated Efficiency		
~~123~~	~~115~~	~~1.42~~			-	1400	23.3	~~1300~~ 0	~~23~~ 0	0						
122	23	2.81	"	1.4				1300	21.6	0	0	0	1.4			Without fans
118	118	9.204	0.08	7.78				1120	18.6	95	16.5	1.57	9.35	1100		
119	119	8.33	0.06	6.9				1070	17.83	93	16	1.49	8.4	1100		
130	130	9.36	0.07	7.944				1215	20.25	94	15.7	1.48	9.44	1200		
134	134	10.19	0.07	8.8				1270	21.17	94	15.7	1.48	10.3	"		
~~134~~	~~119~~	9.38	0.06	8.0				1240	20.6	97	15.7	1.52	9.5	-	after 2½ hours	
				Test	with	brushes	field	28th	June.							
120	119	9.36	0.07	~~7.83~~				1080	18.0	85	16	1.36	9.23	-		
120	122	8.64	0.06	7.16				"	-	87	16	1.39	8.55	1150	after 2½ hours	

The armature temp after stopping was 185° F air 95° F Rise 100° F.
- field " " " " 158° F " " " 73° F.

* - armature - - - - 175° F - 75° - 100° F
brushes field 152° F - 75 77° F




RD
CTION.
DD.
Runs per second.

Test of a small 9" fan made by the E.G.B.C. at their New York Works. 27th June 31.

This fan has six blades, weighs 194 gms, and has a full diameter of 9". Inclined at an angle of $\tan^{-1} 0.61$ or 31° with the plane of revolution the plane angle of the fan is nearly 38°, and each blade is slightly bent about the central line. It was driven by the 1/8 H.P. Smart motor floated in the dynamometer.

Pitot	Speed r.p.m.	f fan r.p.	Balance	Moment	6/5th Moment	Energy watts	deflection	$\tan\theta$ 12·75°	θ	cos θ	effective d when 13714	effective d when 36·5	pressure per sq.cm.	Dist. of plate
1	443·5	7·4	502	100	0·616	0·456	0·3	0·02353	1°·21′	0·9997	13714	102	0·0074	12"
2	823·6	13·73	5·5	275	1·695	2·328	1·2	0·09411	5°·23′	0·9956	13681	411·1	0·430	
3	1109.	18·48	7·5	375	2·312	4·272	1·8	0·14112	8°·2′	0·9902	13611	574·4	0·6827	
4	1457.	24·25	11	550	3·391	9·48	2·5	0·19611	11°·6′	0·9813	13489	85·6	0·0635	
5	1869	31·15	17·5	875	5·394	16·81	4·5	0·353	19°·27′	0·9429	12961	154·1	0·1188	
6	2059	34·32	23	1150	7·088	24·33	6·0	0·4707	25°·12′	0·9028	12414	205·5	0·1652	
7	2297	38·28	28	1400	8·630	33·054	7·25	0·5687	29°·38′	0·8692	11944	248·3	0·2079	
8	2725	45·42	37	1850	11·40	51·79	8·5	0·6668	33°·42′	0·8320	11433	291·2	0·2528	
9	855	14·25	4·5	225	13·87	1·98	1·	0·0784	4°·29′	0·9969	13700	34·23	0·025	36"
10	1267	21·1	10	500	3·082	6·502	1·5	0·1177	6°·43′	0·9931	13651	51·4	0·0374	
11	1552.	25·87	145	725	4·470	11·56	2·5	0·1961	11°·5′	0·9813	13489	85·6	0·0635	
12	2012	33·5	21·5	1075	6·626	22·19	3·7	0·2903	16°·11′	0·9611	13210	126·7	0·0960	
13	2344	39·1	29	1450	8·938	32·95	4·4	0·3453	19°·3′	0·9452	12991	150·8	0·1161	
14	2867	47·8	37	1850	11·40	54·49	6·0	0·4707	25°·12′	0·9028	12413	205·5	0·1654	

Problem:-

To find the mean distance between the centres of adjacent molecules in air, on the assumption that these molecules are particles similar and homogeneous spheres arranged in cubic order at equal distances.

Let r be the molecular radius

Then d the molecular intercentral distance $> 2r$ or say $2nr$

The number of molecules in one line 1 cm long is d^{-1}

" " " " one plane 1 sq cm. " d^{-2}

" " " " volume c.c. " d^{-3}

∴ the mass of each molecule must be $7\cdot8\, d^3 = m$

If g be the gravitation constant, then for a cubical grouping the total attractive force acting across any surface adjacent to a plane of molecules is $\frac{m^2 g}{d^4}\left(1 + 2\cos 45° + \frac{4}{3+3\sqrt{2}} \cos 50° + 0\cdot8\cos 60° + \frac{4}{3}\cos 60° + \frac{4}{9}\cos 65° + \frac{4}{4} + \frac{4}{5}\cos 20° + \frac{2}{3}\cos 35° + \text{&c}\right)$

The limit may be perhaps $\frac{5\, m^2 g}{d^4}$

The force of cohesion in 1 sq cm^2 of air is 6×10^3

and $g = 6\cdot5 \times 10^{-8}$

∴ the pull exerted by each molecule is $\frac{5\, m^2 \times 6\cdot5 \times 10^{-8}}{d^4} = \frac{3\cdot25\, m^2 \times 10^{-7}}{d^4}$

and by all the molecules in one cm^2 section $3\cdot25\, m^2 d^{-4} \times 10^{-7}$

$= 3\cdot25 \times 61\cdot8 \times d^2 \times 10^{-7} = 2\cdot01 \times 10^{-5} d^2 = 6 \times 10^3$

$\therefore d^2 = 3 \times 10^{14}$

$d = 1\cdot7 \times 10^7$

It is perfectly hopeless that Newtonian gravitation can account for cohesive forces

Electromagnetic Design for An Alternating Transformer of 20 kw.

Volts on Primary 1000
" " Secondary 2600
Turns " Primary 700 Secondary 63
" " Secondary 182 calculated 188 allowed for leakage loss. Sec. calculated. 65 allowed
Drop " Primary 15 volts at full load
Current " " 1.5 " " "
Resistance " " .010 ω hot.
Drop " Secondary 2.5 volts at full load 1.0 volts at full load
Current " " 5 " " " 16.6 "
Resistance " " 0.5 ω " 0.06 ω

At 1100 rpm. we have 17600/60 = 293.3 rev per sec = 1146.6 ω avg 1145 ω
Then $f = 911$. Then $\phi w \& A = 1141 \times 10^7$
If ϕ be 14000 $A = \frac{1141 \times 10^7}{911 \times 7.00 \times 4 \times 10^7} = \frac{1141 \times 10^7}{2.55 \times 10^9} = 58.3$ sq. in.

Allowing 60 sq: cms, we have a square core 7.75 in length of edge. say 7.9
The external ring must be 3.875 cms. broad. say 4.0.

The mean turn of the coils will be 1½'
700 turns of primary = 931' - 93' per ohm = # 20 B.W.G. 0.035"
d.c.c. to 0.044" = 2.1169 = 0.01367 sq: cms. × 700 = 9.57 sq: cms

188 turns of secondary = 2.80' for 0.5Ω = 500/1000' per ohm = # 12 B&S 0.0808"
178 " " = 0.88' " " = # 12 B&S 0.0795"
d.c.c. to 0.079 = 0.2362 = 0.05579 sq: cms × 188 = 10.49 sq: cms.
Including insulation space, allow 25% extra = 13 sq: cms. to each coil
or 26 sq: cms. in all.

We think have for the internal radius of $\pi r^2 - 16 = 52$
from which $r = 4.3$ Allow 7.5

If the plates are of 0.007" iron there will be 443 of them.
The area of metal in the disks will be 63·62 − 27.34 = 35.28 sq. ins.
415·5 − 176.7 = 238.8 sq. cms.
" " " plates = 114.5 × 7.9 = 1146 sq: cms.
" " " both 353.4 sq: cms × 7.9 = 2792 c.c. of iron
allowing a sp. g. of 7.84 = 21.9 Kgms = 48.27 lbs.
The weight of the guard plates will be 1 lb: each or 50 lbs. of iron.

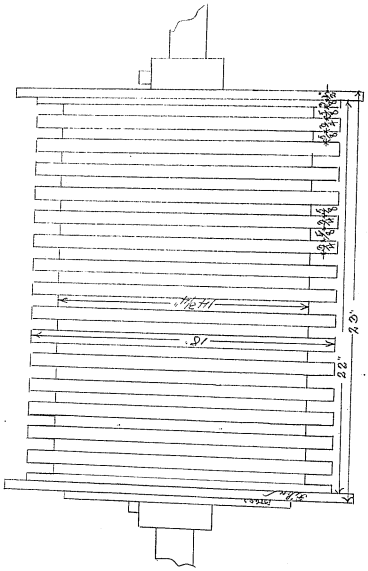
930' of # 20 B.W.G. @ 0.003712 = 3.45 lbs. 1565 gms
250' " # 12 B&S @ 0.0198 = 4.95 = 2245 Total copper 8.4 lbs. 3810 gms

		lbs.
Total weight without shell iron disk	21900	48.27
Covers	900	2.
	22800	50.27
iron any	8565	3.45
Secondary	2245	4.95
	26610	58.67

Cost 5 Olbs. of iron @ 6 c. $3.00 0.15 per lb.
8.4 " " copper @ 30c. 2.52 0.126 " "
$5.52

add labor and shell.

Winding of secondary for 60 volts [65/65] turns of # 12 B&S 0.809" d.c.c. to 0.121"



Determination of the Winding for an Ore Separator.

28th June 97.

The surface of this separator is 143.2×58.4 round 2×1693
$= 8362 + 3266 = 11,628$ sq. cms.

Allowing 30 sq. cms. per watt gives 387 Watts at 120 volt = 30}
" 25 " " " 465 " " " = 387}

Resistance = $120/3.87 = 31.02\,\omega$ @ 60° C.

There are 16 grooves each $0.635'' \times 1.625''$ and the resistance in each is $1.938\,\omega$ @ 60° C. The mean length of each turn is $17'' + 1.4'' \times \pi + 1.4'' = 23''$

Let d be the diam: of the wire cms.

D " " " " " "

$d + 2t = D$ " " " " "

Then if n be the no: of turns per groove

$n(d^2 + 4dt + 4t^2) = 1.4 \times 3.8 = 5.32$ sq. cms.

$\frac{4 \times 42.7\, n \times 1750}{\pi d^2} = 1.94 \times 10^9$

$9.51 \frac{n}{d^2} = 1.94 \times 10^5$

$\frac{n}{d^2} = 2.04 \times 10^4$

$\frac{d^2}{n} = 0.416 \times 10^{-4} = 4.16 \times 10^{-5}$

$d^2(d+2t)^2 = 5.32 \times 4.16 \times 10^{-5} = 2.214 \times 10^{-4}$

$d(d+2t) = 1.488 \times 10^{-2}$

$d = 1.20 \times 10^{-1} = 0.12$ cm $= 0.0472''$

Nearest is #17 B.W.G. $0.0453'' = 0.1151$ d.c.c. to $0.0465'' = 0.1181$

There will be 12 turns and 32 layers = 384 turns say 380 in each groove. $380 \times 44 = 16720'$ for $1.94\,\omega = 862'$ per ohm @ 60° C. #13 B.W.G.

$1.94 \times 173.8 = 350' = 250$ turns $= 25$ layers + 10 turns.

#18 B.W.G. $0.049'' = 0.061''$ d.c.c. $= 9$ turns per layer and 25 layers
$= 225$ turns. $= 315'$

$1.94 \times 763.9 = 1480' = 387$ turns $= 19$ turns per layer and 30 layers
$= 10$ " " " 25

$1.94 \times 1.48 = 2.87$ lbs: in each groove and 46 lbs: in all.

Result #18 B.W.G. d.c.c. $0.049''$ c. to $0.057''$

$n(d^2 + 4dt + 4t^2) = 1.4 \times 3.8 = 5.32$ sq. cms.

$\frac{4 \times 135.3 \times 1750}{3.1416} \times \frac{n}{d^2} = 1.94 \times 10^9$

$3.015 \frac{n}{d^2} = 1.94 \times 10^4$

$\frac{n}{d^2} = 6.43 \times 10^3$

$\frac{d^2}{n} = 1.55 \times 10^{-4}$

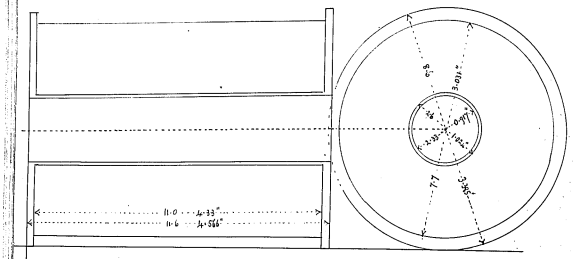
$d^2(d+2t)^2 = 1.55 \times 10^{-4} \times 5.32 = 8.24 \times 10^{-4}$

$d(d+2t) = 2.87 \times 10^{-2}$

$d = 1.69 \times 10^{-1} = 0.169$ cm $= 0.0665''$. #16 B.W.G. nearest.

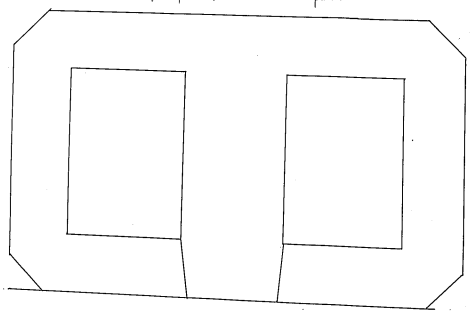
8½ lbs. of wire fit in each groove. $= 1.94\,\omega$ @ 60° C. $= 44.25$ lbs. per ohm.
$=$ #14 B.W.G. $0.064''$. d.c.c. to $0.071''$.

#16 B.W.G. $= 44.58$ lbs. per ohm: $= 1.8\,\omega$ @ 60° C. $= 2.88\,\omega$ in all.



5·½ lbs. of # 19 B.W.G. 0.042" s.c. to 0.045"
1000 feet, 1900 turns, 22 layers of 95 turns each.
Res: of instruments @ 7·2Ω

Full size plan of one sheet iron plate.



Design for a Phonoplex coil intermediate in power between 2 & 3. (28)
Book Turns 91.

In book II pp. 93 & 141 are given the determinations of these coil #2 & 3. The best of the same appear on p. 101.
The length of this new coil may be midway between the length of #s 2 & 3, and the coiling space of wire increased 50%, retaining the same resistance, and adding 50% to the cross section of core.
This gives with the notation of II p. 101

Dimensions of #2 L = 10·6 l = 10 x = 6·35 y = 2·15 z = 1·9 R 5·83Ω
" new coil L = 11·6 l = 11 x = 7·77 y = 2·6 z = 2·38 R 5·83Ω

The coiling space in this instrument is $0.7854\,(7.7^2 - 2.6^2) \times 11 = 452.4$ c.c.

$$d = -\frac{b}{2} \pm \sqrt{\left\{\left(\frac{b}{2}\right)^2 + 1.535 \times 10^{-3} \sqrt{\frac{452.4}{8.83}}\right\}}$$

$$= -0.007 + \sqrt{(49 \times 10^{-6} + 1.535 \times 10^{-3} \times 8.824)}$$

$$+ \sqrt{(0.49 \times 10^{-4} + 1.354 \times 10^{-2})}$$

$$+ 1.164 \times 10^{-1}$$

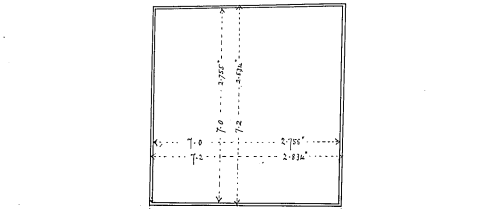
$$= 0.109 = 0.0429" = \#19\ \text{B.W.}\ 0.042"\ \text{nearest}$$

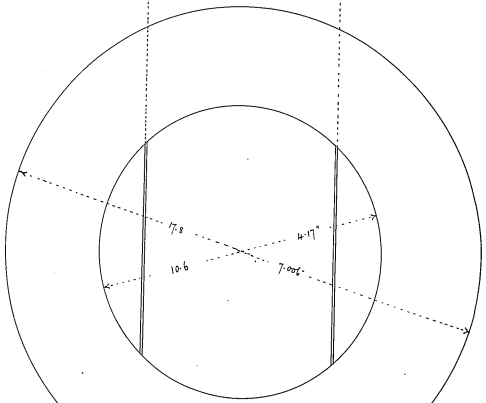
counted to 0.045"

There will be 95 turns and 22 layers = 1900 turns
The mean turn will be 2·027" diam - 6·367" circ = 0·53'
Total length 1900 × 0·53 = 1007'
The length per pound of this wire @ 20°C = 170·9 5·83Ω = 996.4'
The total number of turns = 1880
The weight per turn is 0·9132 lbs × 5·83 = 5·324 lbs.

Description of a Westinghouse transformer marked no 4, and received from Schenectady Works. 20 IV 7

Primary coil 676 turns (26 layers of 26 turns) # 19 B.S. 0.036" 81·0Ω
Secondary " 60 " 6 " 10 " # 8 B.S. 0.1285".
Weight of iron and copper (without shell) 55·5 lbs.
The weight of one plate is 26·5 gms. and its thickness is 0.033 – 0.036"
The length occupied by plate is 23·5, say 22 if compressed making
the effective area section 22 × 3·8 = 83·6 sq: cms.





(2) Design for a six-light Alternating Transformer 1st July 91. (29)

Secondary emf 120 volts × 2 = 240 volt
Primary - 1000 volts
Secondary current 0.5 × 3 = 1.5
. drop at full load 2.0 volts drop 1.3v @ 60°c.
Primary current 0.24 at full load
. drop at full load 15 volt = 60 v. @ 60°c.

Keeping the same cross section of core as that already used on p. 26,
the Primary turns will be 700, the length 930' = 15.5' per ∞ 60°c
= # 28 BWG & 0.014" d.c.c. & 0.025" cross section per wire 6.25×10⁻⁴
for 700 wire 0.4375 sq. in. add 25% = 0.55 sq. in. = 3.548 sq. cms

The secondary turns will be $\frac{240}{1000} \times 700 = 168\ (1.05) = 176$ turns.
176 × 1⅓ = 235' or 176 feet per ohm. @ 60°c = # 17 B.S. 0.0453"
d.c.c. & 0.056". The cross section for each wire will be 3.136×10^{-3} sq. in.
and for 176 turns 0.552 sq. in. add 25% = 0.690 sq. in. 4.45 sq. cms.
Total winding space 8 sq. cms. say 9.

$\pi r^2 - 16r = 9$ $r^2 - 5.092r = 2.865$
$r\pi - (2.546)^2 = 2.865 + 6.487) = \sqrt{9.342} = 3.057$
$r = 5.6$ say 6.

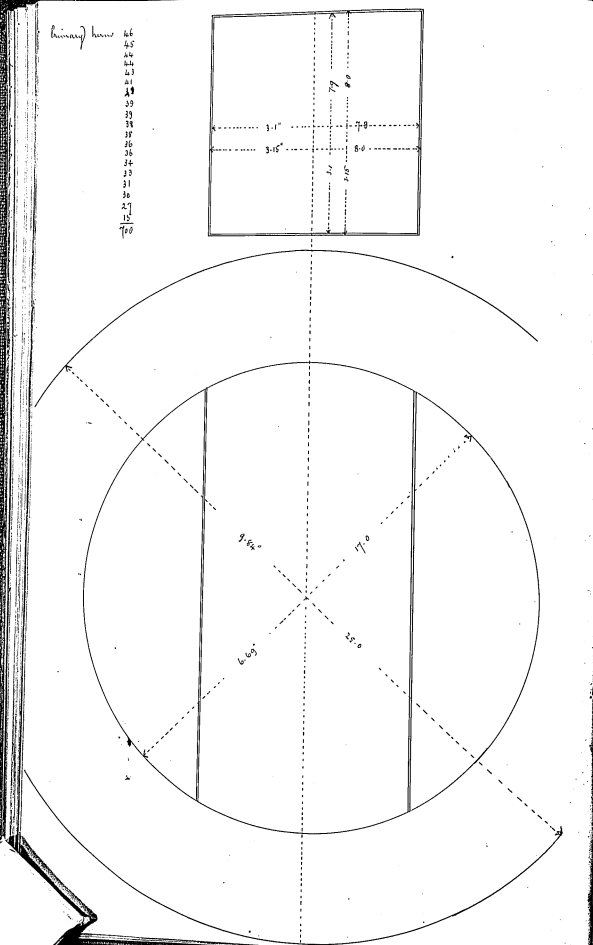
By increasing the induction density to 5000 the core may be reduced to 48 sq. cms or 7 cms: square. Allow with the insulation 7.2.
The thickness of the outside ring will be 3.6.

$\pi r^2 - 14.4r = 9$ $r^2 - 4.585r = 2.865$
$r - 2.293 = \sqrt{(2.865 + 5.258)} = \sqrt{8.123} = 2.85$
$r = 5.14$ say 5.3.

The area of wire is 248.8 sq. cms. − 20 = 228.8 and the thickness 7.2
= 1614 c.c. @ 7.84 = 12.92 kgms = 28.5 lbs.
The copper will be 60 w of # 28 BWG = 0.00986 lbs per ft = 0.56 lbs.
1.33 w . # 17 B.W.G @ 1.08 lbs. per w = 1.44 -

Total copper	2 lbs.	@ .30	= $ 0.60
- iron	20 -	- 6	= $ 1.80
			= $ 2.40

0.10 per limp
0.30 - -
0.40 - -



Design for a 2-KWT. Transformer 2nd July 91.

(30)

Primary Volt age 1000
Secondary " 230.
Core same as that for the 1-KWT. transformer on page 26.
Cross section 60 sq. cms. ∴ 4000.
Mean length of one turn 1.3'
Lamps on secondary — Three wire 40.
Current - - - 10) at full load.
Drop - - 2.5 volts at full load.
Resistance of - 0.25 ω @ 60°C - - .
Turns on - 176.
Length of - 235'.
Resistance - 940' per ohm.
Nearest size # 12 B.W.G. 0.109" d.c.c. to 0.121".
Resistance of 235' of this wire @ 1.0×10^{-3} = 0.235ω 60°C. or 0.26ω @ 100°C.
Weight of 235' " - - @ 0.036 lbs per ft = 8.46 lbs.
Cross section of 180 turns @ $(1.21 \times 10^{-1})^2 = 1.48 \times 10^{-2} = 2.61$ sq. ins. = 16.84 sq. cms.

Current on primary = load 27 allow 2.5%
Drop " " 15 volts at full load
Resistance of " 6 ohms - -
Length 700 turns or 933' = 155.' per ohm @ 60°C.
Nearest size of wire 0.042" # 19 B.W.G. d.c.c. to 0.053".
Resistance of 933' of this wire 6.24ω.
Weight of 933' - - @ 0.00535 lbs per ft = 4.99 lbs.
Cross section of 700 turns of - - @ $(5.3 \times 10^{-3})^2 = (28.09 \times 10^{-6}) = 0.00281$ sq. ins. = 1.967 sq. cms.
= 12.71 sq. cms.

Total cross section 29.55 sq. cms. allow 30% in excess = 38.42 sq. cms.

$\pi r^2 - 16r = 76.84$ $r^2 - 5.093r = 24.46$
$r - 2.547 = \sqrt{(24.46 + 6.49)}$
$= \sqrt{31.95} = 5.65$
$r = 8.2$ say 8.5.

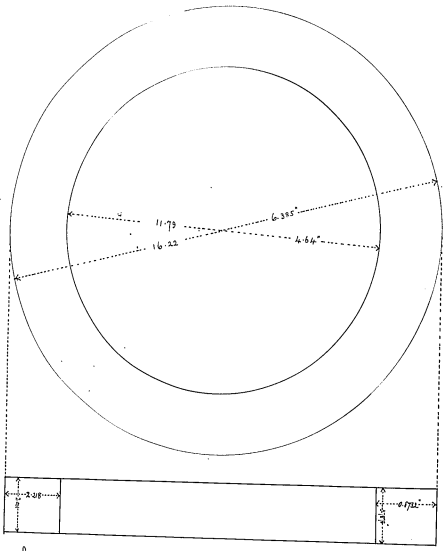
Area of outer circle 25 sq. ins. 4690.88
The interior angle 123°.
Area of inner circle 17 cms 2269.98
$\frac{123}{360} \times 2269.8 = 775.55$ sq. cms. − 30 = 47.55. total winding space 95
395.9 sq. cms is the total area ×8 =
Total volume = 3167.2 c.c. @ 7.54 = 24.85 kgms. = 54.78 lbs.

54.75 lbs of wire @ 0.06	= 3.28	= $1.64 per K.	0.08 per lamp
13.5 " " @ 0.30	= 4.00	" $2.00 " "	0.10 " "
4 lbs - iron guess 0.04	1.16		0.02 " "
	$7.44	" 3.72 " K.	0.20 " "

Surface of transformer plates 1000 side 600. total 1600 sq. cms.
67 energy in primary at full load 37.5 W.
" " secondary " " 25 W
62.5 W

Allowing double this for total waste gives 13 sq. cms per watt.
Length of magnetic cct. 46 cms

Plan and Diametral Section of Plate Ring Test size.



Internal Rad. 5.895. Diameter 11.79 Circumference 37.014 R^2 34.751
External " 8.11 " 16.22 " 50.95 65.77
Mean " 7.003 " 14.005 " 44.0 31.02.

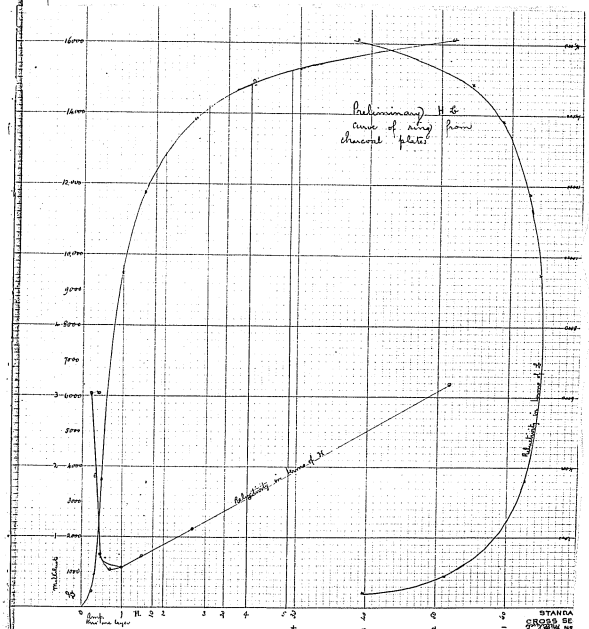
Annular area 97.442

Depth (8 readings) 2.001 0.7878"
Radial breadth (") 2.218 0.8732"
Gross section 4.438 3.613 of iron
Volume 195.3 - 198

Weight in air 1247 grms @ 7.85 = 1589.5 i.e. 1200.5 @ 7.50 = 153.85
Sp. g. of iron & paper 6.39
102 plates each 0.016 = 1.632cm aggregate thickness. × 2.215 = 3.670 sq. cms.
4.438 × 6.39 / 7.84 = 3.618
158.95 ÷ 44.4 = 3.6138 sq. cms. accepted.
153.85 ÷ 44.4 = 3.467 = 3.5 accepted.

Winding: Secondary 2 , each of 50 turns.
Primary 3 layers each of 203 turns.
1st 203
2nd 202 — 405
3rd 203 — 608
608

H = $\frac{608 \times 12.866}{44}$ = 17.767 for 3 layers
= 5.789 - 1



Magnetic test of the sheet iron used in the new Transformers.

These plates were obtained from our rejected armatures for the 1 HP. motor, that has since been left out of use. Each plate has a paper sheet attached to it. The thickness of this plate itself is 0.016" = 0.004 cm. Each plate with one layer of paper has a thickness of 0.023" = 0.059 cm. The mean weight of a single plate is 12.26 grms.

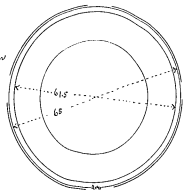
The ring was composed of 102 such plates, total weight 1247 grms. Taking the total weight of iron as 1230 grms the volume = 156.9 c.c.

A plate 10 X 15.8 weighs 18.8555 grms in air = 0.11934 grs. per sq. cm.
16.4384 " " water
2.4185 " less H_2O @ 17°C.
Thickness by weight, @ 7.8 = 0.0155 thick. Sp. g. = 7.796

Source of EMF	EMF at temp		Capacity		Number of Turns		Mean Turns		q		q/ per div.	R. of Q.
B.B. @ 20.6°	1.432		2 μ		5		184.75		2.864×10^{-7}		1.550×10^{-7}	52.66 Ω
t.	Tan. 0.3752	Obsvd. 0.1510	Amp.	Pr. turns	Mag. Pot.	Mean Pot.	R. used in G.	R. of G. obsd.	Secondary turns	q	q	ℓ	H	μ	f
	0.09269	–	0.07464	605	5	18.3	0	52.66	50	2.884×10^{-7}	14.93	427	1.296	329.6	3.435
20°	0.13165	–	0.1021	–	5	140.8	–	–	–	6.333 "	3320	951	1.773	536.3	1.965
30°	0.20345	–	0.1877	–	5	156.1	–	–	–	24.195 "	12,740	3,629	2.739	1329	0.7524
30°	0.411423	–	0.3211	–	5	140.5	11.000	15.266	–	21.82 "	33,310	9.376	5.577	1706	0.586
30°	0.63707	0.07850	0.4929 0.4902	–	5	174.1	–	–	–	26.985 "	41,190	11.770	8.514	1377	0.726
	–	0.173	0.8926	"	5	205.2	–	–	–	31.81 "	48,560	13.870	15.5	893	1.120
	–	0.262	1.352	–	5	220.4	–	–	–	34.16 "	52,150	14.900	23.48	635	1.575
	–	0.292	2.023	–	5	230.6	–	–	–	35.74 "	54,560	15,590	35.29	442	2.262
	–	0.577	2.978	–	5	229.2	–	–	–	37.05 "	56,600	16,170	51.72	313	3.195
	–	2.0	10.32	–	5	273.8	–	–	–	42.44 "	64,790	18,510	179.2	103.3	9.651

To take a practical case, let us consider the diagrams actually given with the Fritsche patent and here reproduced in all essential particulars. Assume the actual machine to be ten times as large.

Four pole
126 wire all round
63 shown in upper
63 " " under layer
Breadth 51
480 revs. per min:
8 " sec:
$\phi = 1.0 \times 10^6$



Breadth of pole 50 degrees,
35.4 actual breadth.
1253 sq: cms:

$e = \phi \cdot 8 \cdot 63 \cdot 4 = 204.6$ volts.

The length of rod on the arm. = $126 \times 1.414 \times 51 = 9088$ cms
- breadth " " " = $200 \div 63 = 3.174$
- depth " " " = $\frac{6.5 - 6.15}{2} = \frac{.35}{4} = 0.875$
- cross section " " = 2.777 sq: cms $\times 0.707 = 1.964$
- resist ance " " = $\frac{9088}{2.777} \times .144 = 3273$ ems $\times .644 = 14629$
- virtual " = 1858 cms.
= 0.00248Ω 18 microhms per cm.

Now take a gramme ring, poles square 1253 sq: cms 35.4 × 35.4 armature 35.4 broad ½ deep.

$e = 204.6$ volts with $w = 252$

The length of rod on the arm. = $252 \times 35.4 = 8920$ cms $\times 3 = 26760$
- breadth " " " = $200 \div 126 = 1.587$
- depth " " " = 0.875
- cross section " " = 1.389
- resistance " = $26760 \times 1.389 = 19270$
- virtual " = $19270 \div 16 = 1204$
= 0.00217Ω 1.8 microhms

Mathematical analysis of the value of the Fritsche winding for multipolar armatures. 4th July 91.

The patent applies to (1) multipolar drum armatures.
(2) disk armatures.

(1) Drum armatures. Let
- p = the number of poles counted round the ends
- d = " diameter of the armature body
- b = " breadth " " "
- w = " number " " wires counted round the arm
- ϕ = " flux from one pole into the armature
- n = " revs. of arm: per sec.
- m = " fraction of emf to be lost in arm at load

Then $b = \pi d / p$.

At culmination $p\phi/2$ lines are enclosed in any one loop of p wires, and this is reversed in the $1/p$th part of a rev:, that is to say it is emptied in the $1/p$th part of a rev: or the $1/2p$th part of a second, so that the emf in each loop $= 2pn \cdot p\phi/2 = 2p^2 n\phi/2 = np^2\phi$
But there are w/p such loops active
total emf pumped
And since there are two circuits in parallel, not one in series,
the terminal emf $e = \frac{p}{2} wnp\phi$

The length of rod on the arm. $= wb\sqrt{2}$
- breadth " " " $= \frac{\pi d}{w} = \frac{2\pi d}{w\sqrt{2}}$
- thickness " " " $= \frac{b}{2}$ where b is the total depth of winding for area $= \pi d b / p \sqrt{2}$

The total resistance $r = \frac{\rho \cdot wb\sqrt{2} \cdot w\sqrt{2}}{\pi db} = \frac{2bw^2\rho}{\pi db}$ ρ being the working resistivity.

But since this is divided into two circuits,
virtual $r = \frac{bw^2\rho}{2\pi db}$

If W be the power of the machine $W = me^2/r = \frac{m p^2 w^2 n^2 \phi^2 \cdot 2\pi db}{4 b w^2 \rho}$

$W = \frac{mp^2 n^2 \phi^2 \pi db}{2b\rho} = \frac{mp^2 n^2 \phi^2 \pi h}{2\rho}$

Now compare with this an ordinary multipolar gramme-ring, having the same p, w, d, m, n, b and ϕ.
Each wire must now be carried underneath the ring whose depth cannot be greater than $0.7\,b$ under Fritsche conditions and may be estimated at $0.35\,b$.

Then $e = \phi n w$
The total length of rod $= 2.75\,bw$
the area $= \frac{\pi db}{w}$
total resistance $= \frac{2.75\,bw^2\rho}{\pi db}$
virtual res: $= \frac{2.75\,bw^2\rho}{p^2 \pi db}$

For the power of this machine $W = \frac{m\phi^2 n^2 w^2 \cdot p^2 \pi db}{2.75^2\, bw^2 \rho}$

$= \frac{mp^2 h \phi^2 n^2}{2.75^2 \rho}$

Theoretically the power of the Fritsche machine is greater by 37%.

Fritsche Multipolar Dynamos continued.

2nd Disk armatures. Let
R = ext: radius of disk
r = radius of inner conductor junctions.
w = no: of rods counted all round (both sides)
p = number of poles on one side of the disk.
ϕ = the flux through the armature from one pole
n = revs: per sec:
b = breadth of disk.
m = drop coeff:

Then at any culmination the flux enclosed by one loop of w wire is $\frac{\phi p}{2}$ and this is emptied in the $\frac{1}{2p}$th part of a revolution, or in the $1/2npth$ part of a second. The emf in the loop is thus $\frac{\phi p}{2} \cdot 2np = np\phi$, but there are w/p such loops active whose total emf. is $\frac{w}{p} np\phi = nw\phi$ and since this is divided into two circuits $e = \frac{1}{2} \phi nw$

If θ be the angle that is made by the rods with a radius at the point of inner connections, the length of each rod $= (R-r)\sec\theta$

The total length $= w(R-r)\sec\theta$
- breadth $= \frac{2\pi r}{\frac{w}{2}} \cos\theta = \frac{4\pi r\cos\theta}{w}$
- thickness $= \frac{b}{2}$
- area $= \frac{4\pi r\cos\theta}{\frac{1}{2}w} = \frac{2\pi r\cos\theta}{bw}$
- total res: $= \frac{w(R-r)\rho\sec\theta \cdot bw}{2\pi r\cos\theta} = \frac{bw^2\rho(R-r)}{2\pi r\cos^2\theta}$

virtual res $= \frac{bw^2\rho(R-r)}{8\pi r\cos^2\theta}$

Power of the machine $W = me^2/\rho = m\frac{b^2}{4}\frac{\phi^2 n^2 w^2 \cdot 8\pi r\cos^2\theta}{bw^2\rho(R-r)}$
$= \frac{mb\phi^2 n^2 w \cdot 2\pi r\cos^2\theta}{b\rho(R-r)}$

Compare with this a gramme-ring armature of same carrying flux capacity, b, n, $\frac{w}{2}$, w and ϕ, but with the pole exterior to the ring, and the ext: diam: of the armature body to be $\frac{R+r}{2}$ while if s is the polar surface of a Fritsche magnet $\frac{s}{2b}$ is the cross section of the armature and the breadth $= 1.414\sqrt{\frac{s}{2}}$ the depth $\sqrt{\frac{s}{2}}$ winding depth d.

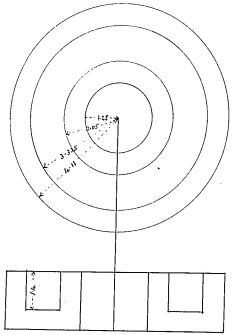
$e = \phi nw$
The length of rod $= w \cdot 2.75\sqrt{2s}$
- breadth $= \frac{2\pi(R+r)}{w}$
- depth $= \frac{b}{2}$
- area $= \frac{\pi b(R+r)}{w}$

total res: $= 2.75\sqrt{2s} \cdot \pi b(R+r)\rho$
virtual res $= \frac{2.75\sqrt{2}\sqrt{s}\ \pi b(R+r)\rho}{b^2}$

The power of the machine
$W = \frac{m\phi^2 n^2 w^2 b^2}{2.75 \times \sqrt{2} \times \sqrt{s} \times \pi b(R+r)\rho}$

$\frac{W}{W_1} =$

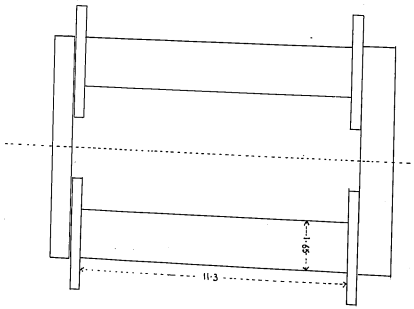
Full size plan
and diametral section of clutch.



6.5 ins - 33.18
4.2 - 13.85
annulus 19.33 sq ins
X 1.4 " 27.062

$\frac{1}{2}$ 22 ins 53
6.65 " $\frac{3\frac{1}{4}\times 6}{12}$
$\frac{4.1}{2.54}$ $\frac{13.2}{5.07}$
8.13

Full size plan of magnet.



On the winding for a magnet and two clutches in the arc dynamo regulator. 6th July 91.

The emf permissable to work one clutch at a time is 2 volts, which with a current of 2 amp would generate 4 watts. The resistance of the coil is to be 1 ohm.

The coiling space being $\frac{1}{4}$ of 27 c.c. we have.

$$d = -0.012 + \sqrt{(0.012)^2 + 1.535\sqrt{27}\times 10^{-3}} + \sqrt{(0.0001444 + 7.976\times 10^{-3}} + \sqrt{8.93\times 10^{-2}} + 0.0893$$

$= 0.0773$ or $0.0304"$ nearest size = 21 B.W.G. Diam: $0.032"$ d.c.c. b $0.0414"$ = 10 turns per layer and 11 layers = 110 turns. The mean diam = $2.117"$ circ = $6.65"$ = $0.554'$ and the total length $60.4' = 61$ feet. = $0.703\,\Omega$

If the thickness of plate is 0.03 in brass separating magnet

Reluctance = $0.03\left(\frac{1}{16.2} + \frac{1}{8.13}\right) = 0.03(0.0543 + 0.1230) = 0.03\ (0.1773) = 0.005319$

Flux = $416/0.005319 = 78,200$

Interior $\mathfrak{L}$ = 9620, but being in cast iron 6000 may be anticipated.

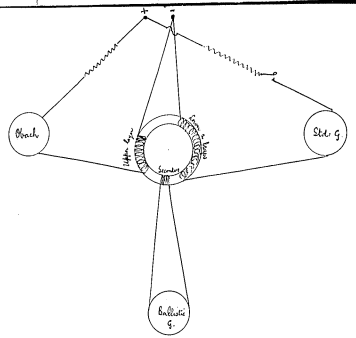
Resistance of strip in parallel with clutches $0.32\,\Omega$.
P.D. on clutch @ 9 amp. 2 volts, with clutch out of circuit 2.89 volts.
Res. of clutch 0.7 @ 60°C.
Wire # 21 B.W.G. 0.032" d.c.c. b 0.0414".
Length 61 feet.
Turns 110, — 11 layer of 10 turns each
Current 2.85 A
Amp-turns 333.
Energy 5.7 watts.

The magnet has to be permanently in the line circuit, and should not have more than 0.20 ω res: The two spools may be in multiple and have 0.4 ω each. The internal diam: is 1.65, the ext: 4.0, the winding area 11 sq: cms, the interflange 11.3, the volume = 154.3. The diameter of wire has therefore to be

$$d = -0.012 + \sqrt{0.000144 + 0.0392\sqrt{\frac{154.3}{0.4}}}$$
$$+ 0.0392\sqrt{3856}$$
$$+ 0.0392\times 4.432$$
$$+ 0.1737$$
$$= 0.1617 \text{ cm} = 0.064" = \#16\ \text{B.W.G.}\quad 0.065"\ \text{d.c.c. b } 0.077".$$

There will be 55 turns per layer, and $0.463"$ depth = 6 layers.
= 330 turns. mean turn = $1.11"$ circ. = $3.495" = 0.29'$
Total length = $96' = 0.268\,\Omega$ @ 60°C.
Resistance of two coils in multiple $0.134\,\Omega$.

Resistance of each spool $0.27\,\Omega$ @ 60°C.
Joint res: of magnet $0.135\,\Omega$.
length on each spool $96'$
Wire # 16 B.W.G. 0.065" d.c.c. b 0.077"
Circular mils 4225 or 8445 emperamp.
Layers 6
Turns 55
Turns on each spool 330
amp. $\frac{2970}{2} = 1485$
Energy 5.5 w
Total magnet 11.0
Drop in magnet $0.2485\,\Omega$



Hysteresis Test of the ring of sheet iron whose BH curve is given on page 31. 6th July 91.

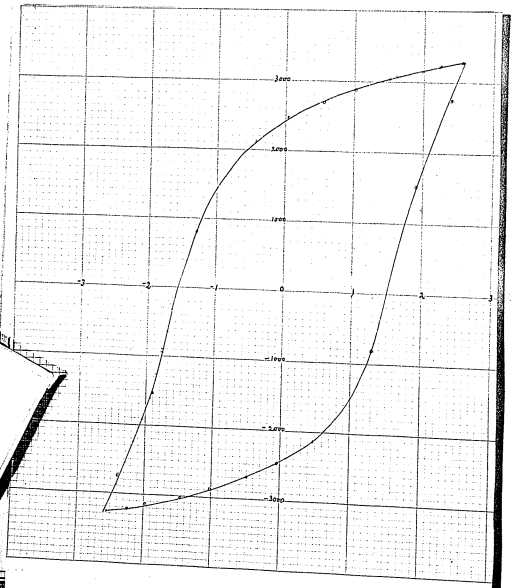
The connections are those of Overhead, and were arranged as shewn.

No. of Obs.	Current in coils 0·7757	Comp.	H	Current in testing coil	Amp.	h.	H+h	No. of Turns	Mean Throw	Ri added to Gs	Res. of Gs coil	½ϕ	Δϕ	Δ'ϕ	Secondary turns
1	0·5935	0·4446	−2·574	0·5503	0·4297	4·974	2·4	6	128·6	0	5280	19958 × 10³	2·1908	6000	570 +2740
2				0·4486	0·3866	2·475	1·901	4	102			158·5	16,736	14782	+1522
3				0·4314	0·3345	3·8732	1·298	5	104·7			162·7	8·590	2455	100 −805
4				0·3378	0·2619	3·032	0·458	6	48·0			74·58	3938	1125	−2135
5				0·2820	0·2186	2·531	−0·043	5	33·75			52·45	2769	791	−2670
6				0·2263	0·17574	2·031	−0·574	5	24·1			37·45	1977	564·9	−2697
7				0·1733	0·1343	1·555	−1·019	6	15·9			24·71	1305	372·9	−2887
8				0·1222	0·09474	1·097	−1·477	6	10·0			15·514	820·6	234·5	−3025
9				0·0670	0·05195	0·6015	−1·9725	5	5·0			7·77	410·3	117·2	−3123
10				0·0378	0·02931	0·3393	−2·235	3	2·1			3·263	172·3	49·23	−3211

No. of Obs.	Source of EMF	EMF at temp	Capacity	Q.	Mean throw.	q. per div.	R. of G.
10	1 Obs 21·5°	1·1431	2 μF	2·282	184·15	1·554 × 10⁻²	5280

The rate $\frac{dB}{dH}$ in the neighbourhood of H = 2·5 is 3000
so that if H had been carried to −H or 2·574, 0·174 further, we should have expected 3000 × 0·174 or 522 more B = 6522 in all whose mean is 3260 ±

The area of the curve is 16·425 sq. in. = 16·425 Obs. × ½π = 13·07 ergs per c.c. per cycle
At 146·6 ~ per sec this is 0·1916 Megalergs = 0·019 Watts per c.c. = 1·1142 Watts per lb. per cycle.



Test of a new Gardew Voltmeter received at the Laboratory 7th July 91. from the E.S.B.S.

The resistance of the instrument @ 20° C. is 450·5 ω.
When placed across the mains with a p.d. of 124 volts, it indicates 117. and takes a current of 0·267 A (117 ÷ 0·3448 33 × 0·7752) indicating a resistance of 464·5 ω.
Calling the resistance 465 ω the multiplying power with 4000 ω is 9.612
6000 ω " 12·91
7000 ω " 16·05
7500 ω " 17·13

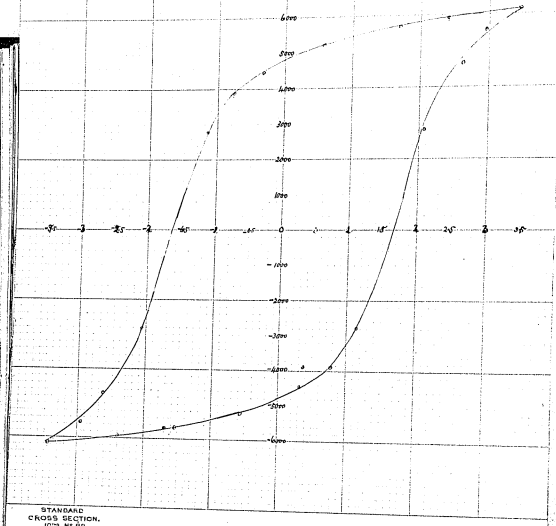
Test of the Bergmann ammeter used at Wing Wing in the execution of four murderers. 7th July 91.

This instrument was received on the afternoon of the day on which it was employed at Wingdong. The calibration was called in question. It was placed in circuit with the 10 lamp under test by the alternating current in the lamp room. It indicated 4·5 A. The lamps take about 0·5 A each.

Data of the latest Fritsche and Pischon multipolar Dynamo received from Mr Henderson on the 29th July 91.

Cablegram

"Have seen Fritsche and Pischon dynamo 300 H.P. 120 revs. per min., outside diameter 2268 mm., width over all 1000 mm. Total weight armature 3204 kilos. Twenty magnets 4495 (4900?) kilos. Grand total weight of machine 9200 kilos. Patterns not finished.



STANDARD
CROSS SECTION.
10" = 1".

Hysteresis Test of Plate - iron Ring 7th July 91.

The same connections and system were employed as is shewn on page 35.
The following measurements were made:-

No of Obs.	Current in Ambulet	Amp. 0.7852	H	Current in test ckt	Amp.	h	H+h	No of Rhms.	Mean Rhm	Rs. of G. ckt	φ.	Δφ	Δ2	δ. ×10⁻⁶	Standard Rhm.
1	2·7931	0.615	−3·560	0·7852	0·6056	7.012	+3.452	5	262	5285	4·084 (×10⁻³)	43,170	12,335	+6167	5·0
2	6·121	0·634		0·7270	0·5636	6·525	2·965	6	244·6		389·1	41,120	11,750	+5589	
3				0·6894	0·5345	6·189	2·629	5	230		358·6	37,910	10,830	+4660	
4				0·6277	0·4867	5·635	2·075	6	190·7		297·3	31,430	8,978	+2808	
5				1·5243	0·4065	4·706	1·146	5	71·8		111·95	11,830	3,380	−2790	
6				0·4821	0·3752	4·344	0·784	5	49·2		151·5	8008	2,288	−3882	100
7				0·4314	0·3345	3·872	0·312	5	69·5		108·35	5727	1.636	−4434	
8				0·3314	0·2569	2·978	−0·585	5	40·3		62·93	3322	949	−52.21	
9				0·2217	0·1718	1·990	−1·570	5	20·8		32·43	1714	490	−5680	
10				0·1302	0·1010	1.169	−2·391	3	10		15·57	8244	2356	−5935	

No of Obs.	Source of EMF	EMF at brush	Capacity	φ.	Mean Rhm	φ per div.	Rs of G.
11	16 c.c. 0.22 K.	1.230	2 μ	2·86	983·5	1.557×10^{-3}	5285

The area of the curve is 17·6 sq. in. = 35,280 Ergs. = 2,807 ergs per cycle. With n = 146·6. w = 0·014115 Watts per c.c. = 0·01632 Watts per kg. 2·413 lbs. sq.

Calculation of the best proportion of iron to copper in an alternating transformer.

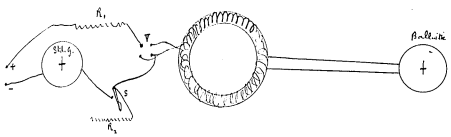
Suppose that the transformer core is a simple ring of mean length $2\pi r$ and of uniform cross section a. Then the mean length of the magnetic ckt: is $2\pi r$ and the volume is $2\pi ar$. If φ is the flux that has to be passed through the ring per cycle there will neglecting foucaults be an equation between the hysteresis waste h per c.c. and $\frac{\varphi}{a}$ of the form $h = f\left(\frac{\varphi}{a}\right)$. If n is the frequency of the alternating current the energy wasted is at the rate of

$$\begin{aligned} T &= n h \cdot 2\pi ar \\ &= 2\pi n ar \cdot f\left(\frac{\varphi}{a}\right) \\ &= 2\pi n ar\, f\left(\frac{\varphi}{a}\right) \\ \frac{dT}{da} &= 2\pi n r\, f\left(\frac{\varphi}{a}\right) + 2\pi n ar\, f'\left(\frac{\varphi}{a}\right)\left(-\frac{\varphi}{a^2}\right) \end{aligned}$$

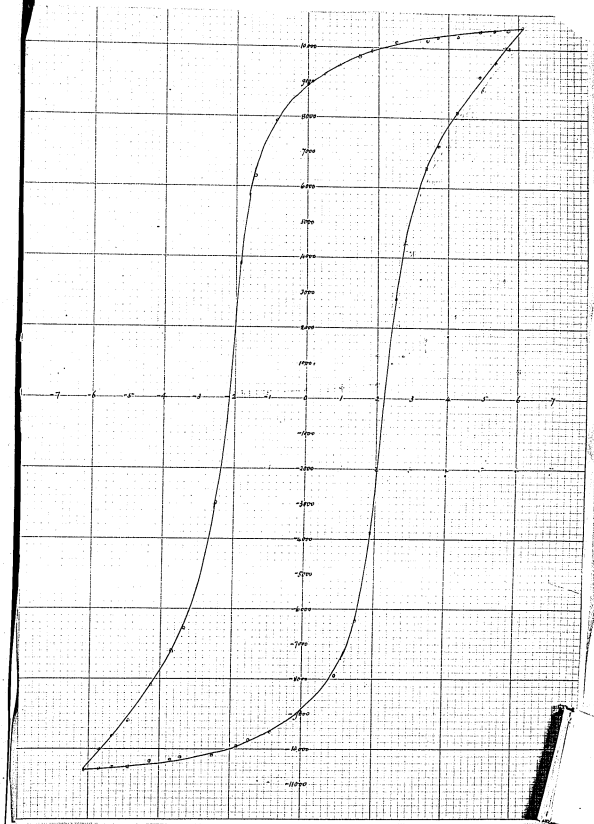
Suppose the hysteresis equation to be as enamved by Steinmetz $h = f\varphi^{1.6}$

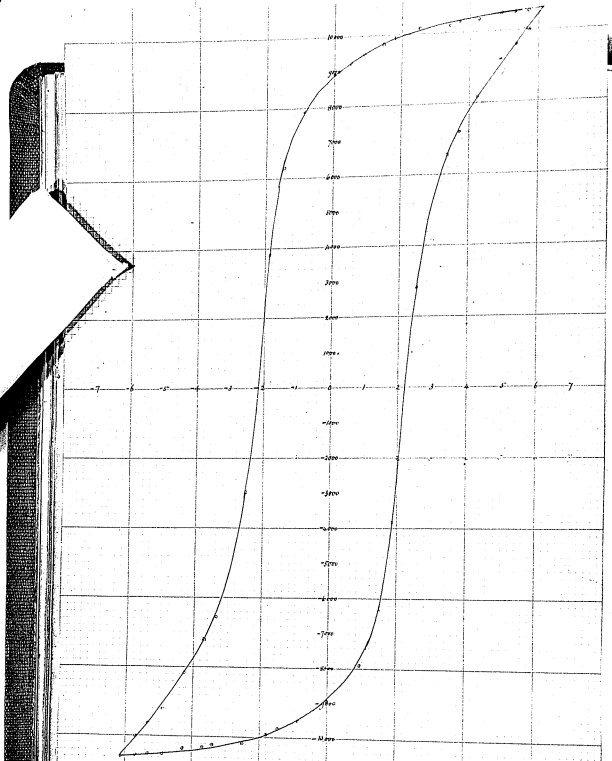
$$\begin{aligned} T &= 2\pi n ar\, f\left(\frac{\varphi}{a}\right)^{1.6} \\ &= 2\pi n r f \varphi^{1.6} a^{-0.6} \\ \frac{dT}{da} &= 2\pi n r f \varphi^{1.6} \cdot -0.6\, a^{-1.6} \end{aligned}$$

So that as regards hysteresis alone, it is advantageous to increase the iron.



$\frac{103.92 \times 1035.}{1138.62} = 94.35.$





Hysteresis Test of Sheet-iron Ring 8th July 91.

The connections on this test were much simplified. The main reverser ∇ was connected up through rec: R, and Std: G, just as in an ordinary IB. test, and the shunted S arranged across an auxiliary rec: R_2. Before every observation this switch was closed, and the rec: R_2 shortcircuited to bring the current up to normal, and then ∇ reversed. To obtain the observation S was now opened, with or without a reversal of ∇ according as the H needed was of the same or opposite sign.

Test No.	Source of EMF	EMF at temp	a	Mean throw	q. per div:	R. of G.
	1 BC. @ 21.5° C. 2 ρ	1.1431	2.862	183.6	1.559×10^{-3}	5280

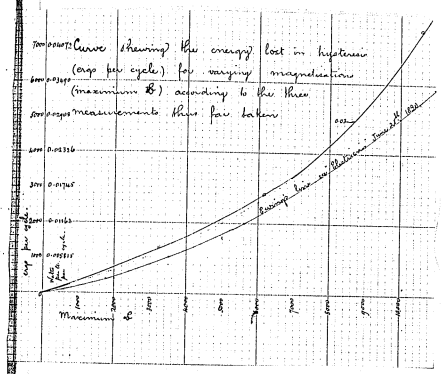
No.	Pd on Siemens	G. amp.	Std. G. 0.7752	Amp.	Accepted current	H	Hyst.	No. of throws	Mean	Reduced to $\frac{1}{2}$ G. est.	Res. of G. est.	ψ	Δφ	Δξ	δξ	Remarks
												10^3				
1	33	0.3498	0.4557	0.3533	0.3515	6.1034		6	312	11000	15280	486.4	76328	21230	10615	100
2	30.15	0.3269	0.4259	0.3317	0.3293	5.7179		5	1.9	0	5280	2.962	156.4	44.7	10.570	"
3	28.8	0.3052	0.40500	0.3132	0.3093	5.3721		5	3.04	-	"	4.739	250.2	72	10.543	
4	26.4	0.2798	0.3644	0.2922	0.2810	4.880		5	5.02	-	"	7.826	413.2	118	10.500	
5	22.75	0.2411	0.3241	0.2481	0.2446	4.249		5	11.4	-	"	17.77	938.3	268	10.350	
6	20.0	0.2112	0.2764	0.2143	0.2132	3.703		5	13.8	-	-	19.96	1054	300	10.315	
7	18.25	0.1936	0.2520	0.1969	0.1953	3.392		3	16.5	-	-	25.72	1358	390	10.225	
8	16.35	0.1745	0.1879	0.1772	0.1744	2.508		5	23.1	-	-	36.01	1901	540	10.175	
9	13.75	0.1533	0.1371	0.1078	0.1056	1.834		5	30.6	-	-	47.70	2519	720	9.900	
10	7.50	0.0795	0.1080	0.0837	0.0837	1.4514		4	36.3	-	-	56.90	3003	860	9.755	
11	4.0	0.04239	0.0605	0.03978	0.0588	0.8922		5	46.7	-	-	72.80	3844	1100	9.575	
12	"	0	"	0	0	0		5	70.2	-	-	109.5	5782	1650	8.965	
13	4.0	0.04239	0.06055	0.03978	0.0588	0.8922		5	115.5	-	-	180.2	9514	2720	7.900	
14	7.5	0.0795	0.1080	0.0837	0.0837	1.4514		5	182.2	-	-	284.1	15000	4290	6.325	
15	9.75	0.1033	0.1371	0.1078	0.1056	1.8334		5	100.0	11000	15280	155.9	23820	6806	3.909	
16	13.35	0.1415	0.1879	0.1472	0.1444	2.508		5	149.8	-	-	311.5	47590	13600	-2953	
17	18.25	0.1936	0.2520	0.1969	0.1953	-3.392		5	252.6	-	-	393.8	60170	17200	-6.585	
18	20.0	0.212	0.2764	0.2143	0.2132	-3.703		5	261.6	-	-	407.9	62320	17810	-7.195	
19	22.75	0.2411	0.3241	0.2481	0.2446	-4.249		5	275.8	-	-	430.0	65700	18775	-8.160	
20	26.4	0.2797	0.3644	0.2822	0.2810	-4.880		5	291.1	-	-	453.8	69340	19820	-9.205	
21	28.8	0.3052	0.4044	0.3132	0.3093	-5.372		5	297.2	-	-	463.3	70780	20230	-9.615	
22	30.85	0.3269	0.4259	0.3317	0.3293	-5.719		5	303	-	-	472.4	72180	20620	-10.005	

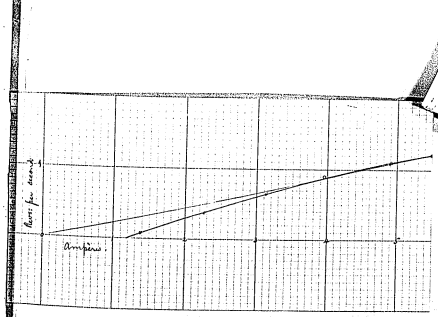
The area of the curve by planimeter is 23.64 sq: in = 94.560 Hrs.
= 7526 ergs per cycle. With n = 1266 W = 0.1101 watts per c.c.
0.013377 watts per lb. effd. 6.402 " lb.

This life test was completed on the 23rd July
The continuous current gave 1300 hr.
" alternating " 2100 " of life. (130 cycles. 4.00 rpm per sec)

1 c.c. of iron has a mass of 7.8 gms.
1 lb. " " " 453.6 " = 58.15 c.c.

$\frac{2200 \times 144.6}{107} = 2.2 \times 1.416 \times 10^{-2} = 0.03111$


Curve showing the energy lost in hysteresis
(ergs per cycle) for varying magnetisations
(maximum B) according to the three
measurements above fair taken
Straight line = Steinmetz formula
Maximum B



Data concerning Edison Experimental Alternator. 8th July 91.

A lamp duration - of - life test was commenced on the 7th July at 11 a.m. The primary current was taken to the lamproom and two Westinghouse transformers operated in parallel with their secondaries in series. This gave a total e.p.d. of 132 volts. 10 lamps were operated at 130 volts, and 10 similar ones of the same order on 130 volt continuous p.d.

On the morning of the 8th at 10 a.m. the two central bands broke on the armature of the alternator. Apparently they simply became unsoldered by the heat. The temperature of the armature at 10 o'clock on the 7th was 200° F on the field 150° F. The temp. on the armature at the time of breaking down was 225° F field 160°

Two wires were found cut on the armature, but there was little other damage. The segment containing the damaged wires was removed.

Estimates of energy developed in armature

Hysteresis.

Generating 1300 volts eff harmonically. the max. would be $1300 \times 1.414 = 1727$ or per segment 108

$n = 19.33$ $w = 512$ $\therefore \varphi = 1.151 \times 10^6$

Half of this however circulates through any one cross section of the armature or 575,000

The mean diameter of the armature is $22.25 - 5.6.5$

" circumference . . 178.

cross section is $31.9 \times \frac{1.414}{2} = \frac{112.3}{159.5}$ of which 0.8 may be iron or 112.3 sq cms

so that the mean maximum flux density except near bolts is $\frac{575}{112.3} = 5120$

The volume of iron in the armature = $112.3 \times 178 = 20000$ c.c. nearly

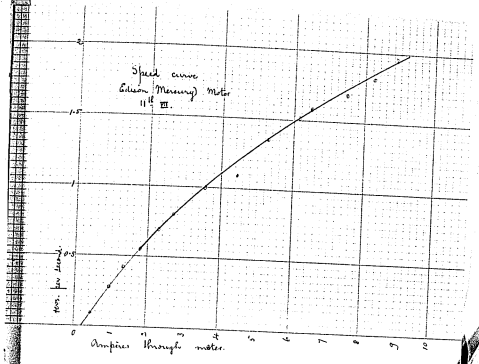
Allowing from the tests of pages 35 and 37 0.038 Watts per c.c. the total energy expended in hysteresis will be 67.5 Watts or allowing for bolt holes and side pieces say 1 Kilowatt.

Preliminary Measurements made with a moving motor operated electromagnetically in the field apparatus shewn on page 35 of Book II. A moving chamber of annular form is contained between two fixed cylinders sealed beneath. The height of this annular space is 10.1 cms and its radii internal and external, 4.55 + 5.4 cms respectively.

The field was excited steadily, and observations of the speed of rotation of moving fillings the chamber observed with varying currents as follows :-

all 12 field spools in series

Watts in Coils.	Amperes in Coils	Watts in field.	Amperes in field.	Speed r.p.m.	r.p.c.				
1.120	5.779	0.355	1.832	74.5	124				
0.947	4.887			66	1.1				
0.767	3.958			53.5	0.892				
0.610	3.148			39.5	0.66				
0.1420	2.271			22.75	0.378				
0.265	1.393			5	0.08				
1.09	5.625			76	1.27				


Speed curve
Edison (Mercury) Motor
11 of III.
Revs. per sec.
Amperes through motor.

Test of mercury meter after 1st modification 18th July.

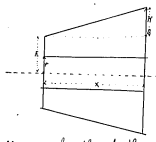
The aluminium blades were bent at the top so as to present their edge only to the mercury surface in the direction of rotation. The test of the last day and page were repeated as follows:-

No. of Obs.	Armature Ohms 0.439	Armature Amperes	Field Ohms	Field Amperes	Speed of armature r.p.m.	Speed of armature r.p.s.	Lamps in armature circt.	Amps per lamp	Lamps in field circt.
1	0·088	0·454	0·355	1·932	5·5	0·092	1	0·454	6
2	0·182	0·939	"	"	16·5	0·275	2	0·470	"
3	0·261	1·347	"	"	25	0·417	3	0·449	"
4	0·348	1·796	"	"	33	0·55	4	0·449	"
4a	0·438	2·261	"	"	41	1·683	5	0·452	"
5	0·519	2·679	"	"	48·5	0·808	6	0·447	"
6	0·692	3·561	"	"	60	1·0	8	0·445	"
7	0·860	4·439	"	"	71	1·083	10	0·444	"
8	1·032	5·325	"	"	81	1·35	12	0·444	"
9	1·186	6·120	"	"	90·5	1·51	14	0·437	"
10	1·266	6·532	"	"	94·5	1·575	16	0·409	"
11	1·446	7·462	"	"	101·5	1·692	18	0·415	"
12	1·603	8·272	"	"	109	1·816	20	0·414	"
13	1·735	8·954	"	"	117	1·95	22	0·407	"
14									

Calibration of Alternating Current Ammeter for Singsing Prison N.Y.
18th July 91.

The instrument having been adjusted mechanically was recalibrated with a scale very similar to its previous one. 0 – 7·5 amperes.
10.09 of platinoid wire was stretched along the floor in a single loop and readings taken of it's p.d. by a Weston 3rd. Class. Voltmeter. The speed of the alternator was 1400 r.p.m. = 23·3 per sec = 373 reversals or 186·5 ~ per sec. The instrument is marked Amps Effective alternating current. Res. 0.09 ohm. Ind: 0.65 at 0, at full load 1·07 millihenrys.

On the coiling of wire on a conical spool



Let x be the interflange length of the spool.
H . . determine difference of radii
r . . internal radius of spool
R . . external . . . at narrow end.
V . . volume of winding space at any point.
$\therefore \rho = R + \alpha x$ where $\alpha = \frac{H}{X}$

$$dV = \pi(\rho^2 - r^2)\,dx$$
$$= \pi(R^2 - r^2 + \alpha^2 x^2 + 2\alpha R x)$$
$$V = \pi\int(R^2 - r^2 + \alpha^2 x^2 + 2\alpha R x)\,dx$$
$$= \pi X(R^2 - r^2) + \pi\alpha^2 \frac{X^3}{3} + \frac{2\pi}{2}\alpha R X^2$$
$$= \pi X(R^2 - r^2) + \frac{\pi}{3}\alpha^2 X^3 + \pi\alpha R X^2$$
$$= \pi X\left(R^2 - r^2 + \frac{\alpha^2 X^2}{3} + \alpha R X\right)$$

If l be the length of the mean turn,
$$l\left(RX + \frac{HX}{2}\right) = \pi X\left(R^2 - r^2 + \frac{\alpha^2 X^2}{3} + \alpha R X\right)$$
$$l = \frac{2\pi\left(R^2 - r^2 + \frac{\alpha^2 X^2}{3} + \alpha R X\right)}{2R + H}$$
$$= \frac{2\pi}{3}\frac{\left(3R^2 - 3r^2 + H^2 + 3HR\right)}{3R + H}$$

Tests of Edison Fan motor on first completion.

(41)

The motor was completed on the 12th July. The following are the details of its winding.

Field spool each 16 layers of 72 turns = 1152 turns in all.
Res: of upper spool 19.16 ω @ 20°C. } #26 B.W.G. 0.018", covered to 0.026".
lower " 19.66 ω " " "
External diameter of spool 5.2 Internal 3.6. Steel core diameter 3.5.
Res: of armature across brushes on one bar 23.46 ω @ 20°C
" " two " 20.56 ω " "
" " one spool 11.73 ω.
Wire #27 B.W.G. 0.016" s.c.c. to 0.022" 290' on each spool.
Ext: diam: of bobbin 4.98" and 3.28 Int: diam. 2.1 Length 2.25 (interflange)
Probable number of turns on each spool 1250, on whole armature 10000.
The following observations were made

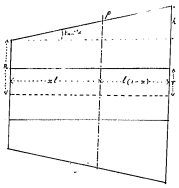
No. of Obs.	Current in Field Amps.	Circuit amp.	Amp turns	Moment	Current in armature (Shunt) amp.	Speed rpm	rps.	Volt at armature	R. of armt.	deg	Dyne	φ	E (no. turns)	Energy in armature watts
1	0.071	0.366	842	1038	0.042	0.217	1520	25.3	122.5	23.5	5.1	117.4	46,420 77,370	9250 15,420	26.6
2	0.129	0.666	1530	1920	0.045	0.232	1400	23.3	"	"	5.25	117.	50,200 83,660	10,010 16,730	28.4
3	0.169	0.872	2005	2520	0.049	0.253	1370	22.8	"	"	5.95	116.5	57,100 95,160	10,220 17,030	31.0
4	0.200	1.032	2375	2955	0.050	0.258	1325	22.1	"	"	6.06	116.4	52,680 87,800	10,510 17,567	31.6
5	0.252	1.30	2990	3760	0.053	0.274	1246	21.9	"	"	6.44	116.	53,000 88,330	10600 17,670	33.5

Area of Annulus: 1.58 wide and 1.6 deep = 2.53 sq. ins. say 2.5

The actual length of wire on one spool was found to be 260 feet and the number of turns 751 making 6000 on the whole armature.

An attempt was made to determine the power of the motor, by setting it up in the floating dynamometer, but as soon as it exerted any appreciable power, it sparked badly at the commutator, and even when driving its fan it gave slight symptoms of spark.

It was therefore decided to increase the number of sections and commutator bars from 8 to 16, and this change was effected on the following day.



In the case of this motor, $l = 2{\cdot}34$, $R = 1{\cdot}67$, $r = 1{\cdot}17$, $h = 0{\cdot}9$
$\alpha = 0{\cdot}385$, $\alpha^2 = 0{\cdot}148$ and the equation becomes

$$x^3 + x^2\cdot\frac{5}{0{\cdot}908} + x\cdot\frac{3}{2}\cdot\frac{1{\cdot}143}{0{\cdot}81} - \frac{3}{2}\cdot\frac{1}{0{\cdot}81}\cdot(1{\cdot}122 + 0{\cdot}270 + 1{\cdot}504)$$

$$x^3 + 5{\cdot}551x^2 + 2{\cdot}632x - 5{\cdot}915 = 0$$

$$x = 0{\cdot}78 \text{ approx.}$$

Problem:- To find the planes perpendicular to the axis which divides the winding space into two equal parts on a spool which is a right conic frustrum with a concentric circular cylindric hollow core. (42)

Let l = the interflange length of the coil parallel to axis.
r = " int: radii of winding space
R = " ext: " " " at remote ends
h = " difference of radii.
$\alpha = \tan^{-1}\frac{h}{l}$
V = volume of winding space
ρ = ext: radii of bisecting plane.
x = coefficient of axial section.

Then by the result of the preceding page:

$$v = \pi l\,(R^2 - r^2 + \tfrac{\alpha^2}{3}l^2 + \alpha lR)$$

$$v_x = \pi l\alpha\,(R^2 - r^2 + \tfrac{\alpha^2}{3}l^2x^2 + \alpha lxR)$$

$$\frac{v_x}{\pi} = lx\,(R^2 - r^2) + \tfrac{\alpha^2}{3}l^3x^3 + \alpha l^2x^2R$$
$$= x^3\cdot\tfrac{\alpha^2}{3}l^3 + x^2\cdot\alpha\,l^2R + x\,l(R^2 - r^2)$$

$$\frac{v_{(1-x)}}{\pi} = \pi l(1-x)\{R^2 - r^2 + \tfrac{\alpha^2}{3}l^2(1-x)^2 + \alpha lR(1-x)\} \quad \text{where } \rho = R + \alpha l$$
$$= \pi l\{(1-x)(R^2 + \alpha^2l^2x^2 + 2\alpha lRx - r^2) + \tfrac{\alpha^2}{3}l^2l^2(1-x)^3 + \alpha lR(1-x)^2\}$$

$$\frac{v_{(1-x)}}{\pi l} = R^2 + \alpha^2l^2x^2 + 2\alpha lRx - r^2 - R^2x - \alpha^2l^2x^3 - 2\alpha lRx^2 + r^2x + \tfrac{\alpha^2}{3}l^2 + \alpha^2l^2x^2\overline{-x} + \alpha^2l^2x^3 - \tfrac{\alpha^2}{3}l^2x^3$$
$$+ \alpha lR - 2\alpha lRx + \alpha lRx^2 + \alpha^2l^2x - 2\alpha^2l^2x^2 + \alpha^2l^2x^3$$

For equality between v_x and $v_{(1-x)}$ we have:-

$$x^3\cdot\tfrac{\alpha^2}{3}l^3 + x^2\cdot\alpha l^2R + x\,l(R^2 - r^2) =$$

$$x^3(-2\tfrac{\alpha^2}{3}l^3 - \tfrac{\alpha^2}{3}l^3 + \tfrac{\alpha^2}{3}l^3) + x^2(2\tfrac{\alpha^2}{3}l^3 - 2\alpha l^2R + 2\alpha l^2 + \alpha l^2R - 2\alpha l^2)$$
$$+ x(2\tfrac{\alpha^2}{3}l^3 - lR^2 + lr^2 + 2\tfrac{\alpha^2}{3}l^3 - 2\alpha l^2R \overline{+} 2\alpha l^2) + lR^2 - lr^2 + \tfrac{\alpha^2}{3}l^3 + \alpha lR$$

$$\therefore x^3\left(\tfrac{2}{3}\alpha^2l^3\right) + x^2\left(2\alpha l^2R\right) + x\{2l(R^2 - r^2)\} - \{l(R^2 - r^2) + \tfrac{\alpha^2}{3}l^3 + \alpha l^2R\} = 0$$

$$x^3 + x^2\,\frac{3R}{\alpha l} + x\,\frac{1}{2}\frac{(R^2 - r^2)}{\alpha^2l^2} - \frac{3\cdot1}{2\alpha^2l^2}\{R^2 - r^2 + \tfrac{\alpha^2}{3}l^2 + \alpha lR\} = 0$$

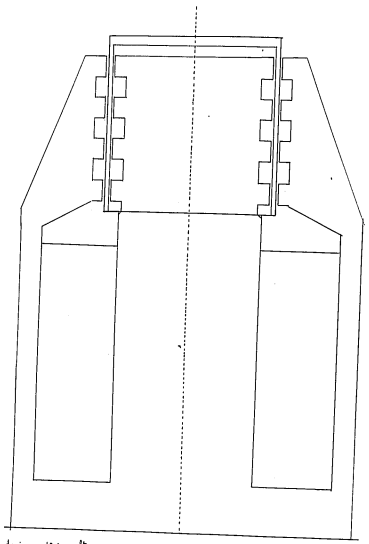
The solution of this cubic equation gives x in terms of l, R, r & α.

Data of the Frequency for different alternating Current Systems in this country and in Europe.

	~	alts. per minute
Edison system	1448·3	17000
Ean Claire "National"	1140	16,800
Westinghouse	138	16,500
Thomson Houston	125	15,000.
Ferranti	67	8000
Lowrie - Parker	88	10,500
Mordey	100	12,000
Lipernowski	42	5000
Kennedy	60	7200
Kapp	80	9600
Gramme	42	5000

Full sized section of copper bell meter.

Cast steel.



E.M.F. of design 120 volts
Res: of field coil @ 60°c. 682·5 Ω
Current in field coil 0·176 amps
Energy . . 21 watts.
Size of wire #29 B&S. 0·013" silk x 0·016"
Nº of layers of 178 turns each 64·5
Nº of turns 11,480
. amp: turns 2000
MMF. 2514
Gap length 0·32
Pole area 41·6
Reluctance 0·00769
Flux 330,000
In iron 16,000.
Length of wire 9760'
. mean turn 0·85'

Thickness of copper bell 0·158 (1/16")
Height . . 6·3
Diam: (ext:) . . 6·3
Clearance inner + outer each 0·079 (1/32")
Starting moment 5·3 grammes - cms

As constructed Ext: diam 6·3 } of bell
Int: . 6·1 }

Ext: diam of inside 3·35"
Int: dia 2·5/8"
Yoke . 2·75"
. axis 8·46"
0·72"

Diam of shaft 0·51 beneath
Length of bell 6·3"
Diameter of flap 0·9 above.

8 poles on external circumference facing 8 on inner
Diameter of external bore 6·27
. internal pole 5·8
Gap 0·385

151g = of #31 B&S. = 9·448' per = = 142,720' × 0·72 = 102,758
turns at 1/0·19 = 0·05809 = 1655 amp: turns

On the Electromagnetic Design of an Edison copper bell meter for continuous currents. 43

Suppose the arrangement to consist of a cylinder of copper of mean radius r and thickness p set midway between two concentric cylinders of iron of radii ρ and R respectively. Further suppose that the true poles on the surfaces of these cylinders are circles of radius p, separated by distances h between centres. Then there will be $\frac{2\pi\rho}{h}$ poles on the inner circle horizontally and $\frac{H}{h}$ vertically, where H is the height of the cylinder. There will thus be $\frac{2\pi\rho H}{h^2}$ poles each of area πp^2 actually and $\pi(p+\frac{p}{2})^2$ for magnetic purposes. The total surface magnetically is

$$S = \frac{2\pi\rho H}{h}\left\{p+\left(\tfrac{p}{2}\right)^2\right\}^2 \quad \text{where } D = R-\rho \text{ , the entrefer is also } \ell = d.$$

If $\mathfrak{M}$ be the magnetic difference of potential between the poles, $\frac{\mathfrak{M}}{d}\cdot\frac{2\pi\rho H}{h^2}\left\{p+\frac{p}{2}\right\}^2 = \Phi$ the total flux, and the local flux is $\phi = \frac{\mathfrak{M}}{d}\cdot\pi\left(p+\frac{p}{2}\right)^2$.

The moment of the moving force on the bell for a current c

$$m = \frac{\Phi c}{2\pi} = \frac{\mathfrak{M}\pi\rho H C\left(p+\frac{p}{2}\right)^2}{d\,h^2}$$

The foucault retarding drag tangentially round any pole $= \alpha' \delta^2 = \alpha'\left(\frac{\phi}{S}\right)^2 = \alpha'\frac{\mathfrak{M}^2}{d^2}$ the moment of the drag is $\frac{\alpha'\mathfrak{M}^2 r}{d^2}$

and the total moment $= \frac{\alpha\mathfrak{M}^2}{d^2}\cdot 2\pi r H = \frac{2\pi\alpha\mathfrak{M}^2 r H}{d^2}$

The oil fluid friction is nearly independent of the radius
. solid . proportional to .

The moment of the moving forces is proportional to the rad: + to $\frac{1}{d^2}$ + to H
. retarding . . . r² . . H

We must therefore make the radius conveniently large and equal to the height of the cylinder.

Taking a mean diameter of 6.25 = a circ: of 19·6"
With H height = 6·3 and arranging four poles in this height 1·5 cms apart there will be room for 13 pole rounds the ring or 52 in all of 0·80 sq: cms. each approximately = 41·6 sq: cms: total pole surface at an entrefer of 2·54/8 = 0·32, a total reluctance of 0·32/41·6 = 0·00769

With a winding of 5 lbs. of #29 B&S. wire 0·013" silk c. & 0·016" there will be 2460' 682·5Ω and 9760' in all. The current will therefore be 0·1758 at 120 volts p.d. and the energy 21 watts. The mean winding space diameter is 3.25" = 0·85', circ: The number of turns will therefore be 9760/0·85 = 11480 and the amp: turns. 2000 the MMF 2514 the flux 330,000 and the density in the core 14,960 amounting to about 16,000 at the neck. The number of turns in one layer $3'' \div 0{\cdot}06 = 187 \times 0{\cdot}95 = 178$ and the number of layers 11480/178 = 64·50 × 0·016 = 1·03". 1.15 allowed

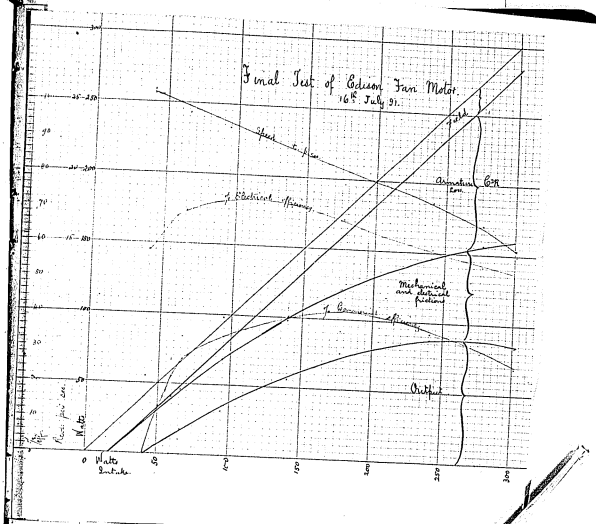
The starting torque will be $\frac{330{,}000 \times 1}{\text{dynes}} = 5290$ or 5·3 gms weight at a rad: of 1 cm: per ampère 62·38 of current.

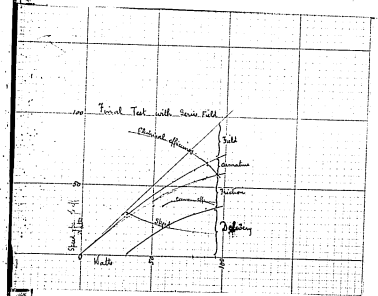
When constructed the current which would just lift 11·2 gms at radius of 0·26 cm = 2·912 cm: gm: = 1·073 amp: and the current that would just when it = 0·1774 amp: = 0·924 amp: mean so that the moment = 5·15 cm: gms: per amp: and the starting friction = 0·15 amp: or 0·039 empe:

Field separately excited. 2 lamps in parallel. Motor driving 1/4th H.P. Pump.

No. of Obs.	Current in field	Energy in field watts	P.D. at armature terminals	Speed	Current in armature amps.	Energy absorbed watts	Rise of temp. in degrees	C.R. drop in armature	C^2R watts in armature	Effort	Speed of armature	No. of rev. of armature
1	0.6295	163	124		0.039	0.2012	25.0	23.8	4.79	1.0	2.4.0	1550	25.8
2					0.068	0.350	43.4		8.3	2.9	40.5	1500	25.
3					0.078	0.402	49.9		9.6	3.9	46.0	1465	24.4
4					0.122	0.630	78.1		15.0	9.5	68.6	1400	23.3
5					0.194	1.001	124.1		23.8	23.8	103.3	1320	22.
6					0.252	1.30	161.2		30.9	40.2	121.0	1180	19.6
7					0.350	1.806	224		43.0	77.7	146.3	1120	19.6
8					0.407	2.10	260.4		50.0	105	155.4	1020	17.
9					0.448	2.311	286.6		55.0	127.1	149.5	920	15.3
10													
11													

No. of Obs.	P.D. on machine	Speed	Current in motor	Energy absorbed	Rise of field	Drop in cable	Energy in field	Energy in armature watts	Rise of temp.	Drop in armature	Energy consuming	Effort
1	123	0.050	0.258	31.7	40.	10.3	2.7	29.	21	5.4	1.4	27.6
2		0.090	0.465	57.2		18.6	8.6	48.6		9.8	4.5	44.1
3		0.100	0.516	63.5		20.6	10.6	52.9		10.8	5.6	47.3
4		0.123	0.635	78.1		25.4	16.1	62.		13.3	8.5	53.5
5		0.138	0.712	87.6		28.5	20.2	67.4		15.0	10.7	56.7
6		0.150	0.776	95.2		31.0	24.	71.2		16.3	12.6	58.6
7												





Trial Tests of Jam Motor 16th July 91.

The number of commutator bars is now 16 and each main spool is wound in four equal lengths of 130 feet ⌀27 SWG. and each main spool is wound

When held on 124 volts p.d. series field. the current is 1·96)
running light . . . . . 0·253)
. . with the E.C. & Co's fans @ 1460 r.p.m. . . 0·335)

With 123 volts at main terminals on fans duty the p.d. at brushes = 111.
The weight of the machine with fans but without ground is 18 lbs.
There is no appreciable sparking at the brushes

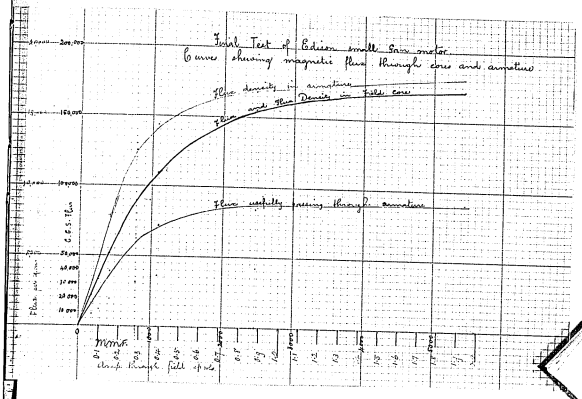
Balance	Moment	6165 Moment	Energy delivered	Total energy absorbed	Electrical efficiency	Commercial efficiency	Friction watts	EMF generated	EMF per bar per sec.	Conditions
		×10⁷								
50 0				141·3	0·581	0		119·2	4·62	Running light
50 ⌀ 17	850	0·5242	13·1	59·7	0·679	0·22	27·4	115·7	4·63	Connected to fans
50 ⌀ 23·5	1175	0·7244	17·7	66·2	0·695	0·267	28·3	114·4	4·69	- - -
100 ⌀ 10 50 ⌀ 20	2200	1·357	31·6	94·4	0·727	0·335	37·0	109.	4·68	Dynamo field S.E.
100 ⌀ 25 50 ⌀ 31·5	4075	2·514	55·3	140·4	0·714	0·394	45·0	100·2	4·56	- - -
200 ⌀ 25 50 ⌀ 14·5	6225	3·839	75·3	177·5	0·682	0·424	45·7	93·1	4·735	1 lamp from 4
200 ⌀ 25 100 ⌀ 20 40 ⌀ 32	7600	4·688	87·5	200·3	0·610	0·364	59·1	81·0	4·34	- - -
200 ⌀ 25 100 ⌀ 20 50 ⌀ 37·5	8375	5·164	87·8	276·7	0·562	0·317	67·6	74·0	4·35	- - -
200 ⌀ 25 200 ⌀ 18	8900	5·488	83·6	302·9	0·494	0·276	68·9	69·0	4·50	2 lamps - -

Trial Tests series field, 17th July 91.

On this occasion there was a slight derived circuit through the field spools and base subsequently corrected, but the effect on the test may probably be neglected.

Speed r.p.m.	r.p.s.	Balances @	Moment	6165 Moment ×10⁷	Energy delivered	Electrical efficiency	Commercial efficiency	Friction	EMF generated	EMF per bar per sec.	C
1800	30	50 ⌀ 0				0·671			107·3	3·577	0·0666
1270	21·16	100 ⌀ 10 50 ⌀ 11	1550	0·955	20·2	0·771	0·353	23·9	94·6	4·247	0·2143
1277	21·3	50 ⌀ 29·5	1475	0·909	19·4	0·745	0·345	27·9	91·6	4·130	0·2663
1020	17·3	100 ⌀ 20 50 ⌀ 17	2850	1·759	30·4	0·685	0·389	23·1	84·3	4·87	0·4032
1020	17·0	100 ⌀ 20 50 ⌀ 28	3300	2·035	34·6	0·647	0·395	22·1	79·5	4·68	0·5069
960	16·0	100 ⌀ 20 100 ⌀ 10 50 ⌀ 14	3700	2·290	36·5	0·615	0·383	22·1	75·7	4·73	0·599

In order to remove the cross between the field coils and the brass, it was necessary to rewind the spools, with 16 layers of 72 turns each. The resistance of the field so rewound was 38·7 ohms instead of 39 ohms, and the cut. drain was 2·08 instead of 2·1.


Total Test of Edison small Size motor.
Curves showing magnetic Flux through cores and armature.
Flux density in armature
Flux and flux Density in field cores
Flux usefully passing through armature
Flux per sq cm
C.G.S. Flux
Mmfs

Magnetic Test of Fan Motor. 16th July 91.

120

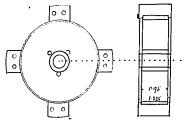
The field magnet was excited by a measured succession of increasing currents, reversed by a switch and the flux through the armature and field-centre observed with 5 turns of wire on each and the ballistic galvanometer.

Wt. of Fe	Sectional area of Core	Ratio of Core	Permeability	q.	Mean throw	q. per div.	Ratio of q.
g	1.8 sq. in. (= 27 sq. cm.)	1.14247	2.9	2.84944	181.95	1.566×10^{-3}	5380

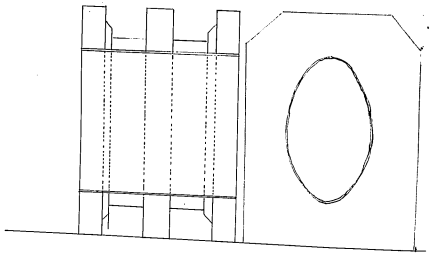
Field

No. of Obs.	Strength	Amps.	Magnetic Force (Ampere turns per inch)	No. of throws	Mean throw	q.	$\frac{q}{5300}$	b	No. of throws	Mean throw	$\frac{q}{10^{-8}}$	q	b.	Number of Armature lines
1	0.15339	0.1644	187.5	4	26.05	4.08×10^{-4}	21,920	2,195	5	9.5	1.488	8,032	3200	16,000
2	0.12379	0.0952	277.3	4	39	6.108	32,860	3,286	5	14.6	2.287	12,305	4925	24,600
3	0.18524	0.1437	418.4	5	61.76	9.672	52,030	5,203	5	23.2	3.633	19,550	7822	39,100
4	0.35150	0.2725	793.6	3	106.3	16.63	89,460	8,946	5	37.1	5.811	31,270	12,510	62,520
5	0.48231	0.3740	1089	5	130.2	20.39	109,700	10,970	5	42.14	6.6142	35,740	14,300	71,480
6	1.0977	0.8510	2478	5	184.1	28.83	155,100	15,510	5	50	7.832	42,140	16,860	84,280
7	1.6808	1.303	3793	5	263.5	31.87	171,400	17,140	5	52.1	8.160	43,910	17,570	87,820
8	2.4142	1.872	5451	2	219	34.30	184,500	18,450	2	53.5	8.38	45,090	18,040	90,180

Full lined sections of suspended coil in vertical plane.



Int. diam. 0.750 Width of slot 0.95
Ext. " 2.75 Breadth " " 1.25



$\frac{104.7 \times 2070}{2174} = 99.66$.

$\frac{104.7 \times 1045}{1149} = 95.14$

Data of the Kohlrausch Electro Dynamometer

20th July 91

66

This instrument was taken down and completely overhauled.
The dimensions of its parts are shewn on the opposite page:-
The number of turns on the suspended coil is marked on it as 130.
Probably 36 layers of about 36 turns each.
Resistance 79.8 ω @ 25° C.
Inductance 1000/100 . 79.85 = 0.30 ᴾ 0.31ᴾ > 0.3 ✕ 2.9ᴾ = 24 millihenrys.
Mass. including brass staff beneath with set screw for clamping wire 28.58 gms. including mirror. Weight of hanger and 0.62 each making total of 29.4 gms.
Diameter of copper wire 0.016 cm. silk covered. The vane in air only increases the 4 to 30 g.
" " suspending wire 0.006 cm.
The torsional modulus of this wire was ascertained as follows:-
33.0 cms. of the suspending wire sustained a sphere of rad. 0.9435 in air, and the period of vibration was 15.35 secs. The weight of the sphere was 26.46 g. The moment of inertia of the sphere is
$26.46 \times 0.4 \times (0.9435)^2 = 10.584 \times 0.2226 = 0.9424$ cm²gm.
The torsional rigidity of the wire is thus $33 \times 6 \cdot 0.9424 \times 4\pi^2/(15.35)^2 = 5.28$
and the torsional rigidity of the material $\frac{2 \times 5.28}{3.14 \times 6^4 \times 10^{-12}} = \frac{10.56}{4072 \times 10^{-8}} = 2.59 \times 10^8$
The winding of the outer coil was altered to the following

Lowest 5 layers of 23 turns on each coil	=	230 turns in all	0.040 in.	0.085	
Intermediate 4	-	12	-	= 96	- - - 1.9116 0.1047 ins. 0.108
External 2	-	4	-	= 16	- - - 1.2846 0.277 ins. 0.330

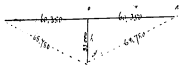
Res. of lowest coil @ 23° C. 5.420
intermediate " 0.4045
outer " 0.8995 ω.

Resistance of suspended system @ 23° C. 104.7 ω.

Made preliminary calibration as follows:-
Current in the large coil 49.5/94.9 = 0.5215) Product 0.00833
" " suspended coil 3.92/182.8 = 0.01597)
Reading on torsion head 39.9
Value of one div. of torsion head = 2.088×10^{-4}
If r be the resistance (non inductive) in the suspension circuit, then $r \delta^2 2.088 \times 10^{-4}$ will be the power in watts delivered through the instrument when δ is the torsion head reading).

In order to make the instrument more convenient and effective, the hair suspending torsion wire was replaced by a wire of copper 0.003". The cup beneath the instrument was removed and a tumbler with a little mercury filled up with water, and a superficial layer of kerosene oil substituted. The vane is plunged beneath the kerosene, in the water and from the vane hangs a fine copper wire 0.002" (0.005) about 5 cm. long with a small brass sphere suspended at its lower extremity. This brass sphere rests on the mercury. This arrangement proved very satisfactory and the following readings were obtained.

No. of Obs.	Res. in 25° C. in suspension	P.D. on suspension coil	Current in suspension coil	Power in watts in coil	Experimental rad. of sphere (Stewart's method)	P.D. on res.	Current in outer coil	Co.	Torsion Heads reading	Co from degree of torsion
1	67.1	0.0978	0.01458	104.7	99.66	67.0	0.6724	0.009802	204.4 +	4.805×10^{-5}
2	"	0.0990	0.01476	"	"	66.2	0.6614	0.009806	205.4 +	4.805 "
3	"	0.0989	0.01475	"	95.14	66.25	0.6615	0.009958	134.2 +	5.111 "
4	"	1.0168	0.01516	"	"	66.10	0.6603	0.009738	95.8	
5	"	1.0146	0.01513	"	"	57.2	0.6013	0.009374	212.5 +	4.412 "
6	"	1.0080	0.0101	"	"	57.0	0.5991	0.009676	155 +	



$df = \frac{\gamma I_0 \cos\theta}{r^2}$

$= \gamma k \frac{dx}{(h^2+x^2)}$

$f = 2\gamma k \int_0^\infty \frac{dx}{(h^2+x^2)^{\frac{3}{2}}} = \frac{2\gamma k}{h^2}\left[\frac{x}{(h^2+x^2)^{\frac{1}{2}}}\right]_0^\infty$ The resultant force of this is $2f\cos\left(\frac{\pi}{2}-\frac{\theta}{2}\right)$

$= 2f\cos(90°-26') \quad 2f\cos(89°\,34') =$

$2f \times 0.007756 = 0.015\,f$

$= 1.6404 \times 10^{-6}$

$= \frac{2\cdot 2\gamma I}{h^2+x^2}$

$= \gamma \frac{4\pi \times 6.285 \times 10^4}{3.3810^8 \times 6.97 \times 10^{-2}}$

$= \gamma \frac{2\pi\cdot 27}{22.7 \times 10^6}$

$= \gamma \cdot 1.693\,6 \times 10^{-6}$

Two wires distant vertically 500 would subtend an angle of $\tan^{-1}\frac{500}{33,000} = \tan^{-1} 1.515 \times 10^{-2}$

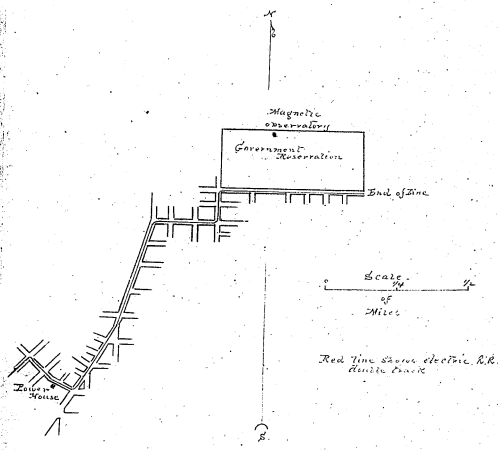
$0.015\,15 = 52'$.

Will $\gamma = \gamma = \begin{matrix} 10\times10^{-5} \\ 0 \end{matrix}$ horizontal component vertical

---

Regarded from a polar point of view, the angle $\theta = \cos^{-1}\frac{33,000}{67,000} = 0.490$ $= 61°\,20'$ and $2\theta = 122°\,40'$. The area of a belt 5 metres wide at a radius of 33,000 would be $2\pi \cdot 33,000 \times 500 = 1000\pi \times 33,000 = 33,000,000\pi$ and the arc embraced is $\frac{122\cdot6}{360}$ of this

$\pi\ 1.0367 \times 10^{13} \times 122\cdot6/360 = 3\cdot53 \times 10^{13}$. The spherical area at this radius is $4\pi(3\cdot3)^2 \times 10^8 = 10\cdot89 \times 12\cdot566 \times 10^8 = 13697 \times 10^{11}$. Consequently the solid angle subtended at the needle by the loop $= 3\cdot53/1\cdot369 \times 10^2$ $= 2\cdot579 \times 10^{-2}\pi$ and the potential of the loop at the needle $= 2\cdot579\pi \times 10^{-2}$ The force will be $= 2\cdot2\cdot579 \times 10^{-2} \times 2/33,000 = 5\cdot158 \times 10^{-3}/5\cdot3 \times 10^4 = 1\cdot563) \times 10^{-7}$ $= 1\cdot9\,6\pi \times 10^{-6}\gamma$



Particulars of magnetic disturbances caused by an Electric Railway on the needles of a Government Observatory at San Antonio Texas. 20th July 91.

These particulars were received unofficially from Mr R. S. Holden of the U.S. Coast & Geodetic Survey 24th July 91.

The electric road has a double track which is all bid electrically return circuit. Car haul from 6 to 23 o'clock. Number of cars not given. The soil is mostly gravel 3 to 5 feet deep resting on white clay of unknown depth, probably over 20 feet. Soil is dry.

The amount of disturbance of the unifilar magnet is about 3 divs = 2·3 minutes of arc in declination. The disturbance on the bifilar magnetometer is about 3 scale divs: equal to $2{\cdot}09 \times 10^{-4}$ dynes. and the vertical force is about 5 scale divs: equal to $7{\cdot}95 \times 10^{-4}$ dynes. Probably the cars start at about 6 o'clock and ends when they stop – at 23. Occasionally a later car is run.

Two hypotheses present themselves. 1st that the rails of the track carry practically all the return current in which case the disturbance is simply electromagnetic action of the loop formed by rails, wire and track or 2nd that the rails carry only a part of the current the rest travelling through the ground over a wide area and the current sheet affecting the magnet. Both these conditions can be active.

1st Supposition. Simple electromagnetic loop.

Assume that there is a single line of wire carrying a current of AEMU in one length 120,700 cms (0·75 mile) whose centre is perpendicularly distant 33,000 cms (0·205 mile) from the needle. The force on the needle due to this current is $\frac{1}{2}8468 \times 10^{-5}$ y acting vertically so that it would be necessary for $2879 \cdot 5/5 \cdot 468 = \frac{1}{2}1{,}357$ or $\frac{72 \cdot 5}{1000}$ ampère to flow along this wire in order to produce the amount of disturbance observed.

The combined action of the track and this line would be to reduce this force to 1·5% of its value in other words the return current would neutralise 98·5% of the force.

2nd Supposition. That a comparatively large quantity of the current passes through the ground and some near the needle.

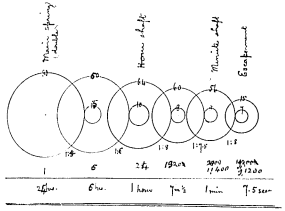
Let c be the current per cm. of breadth and d the mean depth of the layer of soil in which it flows then we have approximately $\text{tot } f = \frac{4c}{h^2}$

Suppose $h = 20' = 600$ $h^2 = 360000$

$$c = \frac{f \times h^2}{4} = 90{,}000 \times f = 90{,}000 \times 3 \times 10^{-4} = 270{,}000 \times 10^{-4} = 27$$

= 27

June 3
9h 15m
June 3
9h 15m
June 3
9h 15m
June 3
9h 15m



Data and Measurements with Edison Clock Meter.

No. 1. 22nd July 1891.

The clock movement is by the Seth Thomas Co. of New York. It employs two mainsprings whose peripheries have 80 teeth working in parallel into a pinion with 16 on a shaft with a 50 toothed wheel working into a pinion of 10 teeth on the hour hand.

On the hour shaft prolonged slide two (vertically) together two crown wheel. The upper one is in diam. and has 116 teeth engaging when in position with a pinion of 16 running horizontal. This pinion is connected with the unit circle of a registering train of 5 – 10 circles. Consequently with the crown locked on the pinion 5·8 units would be registered per hour.

The lower crown wheel is in diam. and has 120 teeth or 1 tooth to 3° of arc, and this moves over a knife-blade carried by an ammeter of the Weston & Marcel Deprez type. This ammeter carried its pointer over an angle proportional to the current. The resistance of its spool is 0·05 ω. A copper wire shunt is so connected that the right deflection is maintained for a given current.

Two levers are moved periodically by cams and springs in such a manner that the crown wheels are depressed five times per hour, to engage with the main counter and ammeter blade. This latter is carried against the action of the current back to zero, and on arriving there trips one lever thus disengaging the crowns.

The maximum throw allowed to the ammeter is 'Thro 60°, but to allow of proper clearance this has to be reduced to 45° or half.

In the improved modification of this instrument, the cam wheel is driven from the 2nd shaft in such a manner as to make one revolution in 3 hours (30:60 ratio). It has 15 double cams, thus tripping every 12 mins. The crown wheels are driven from the hour shaft by an intermediate wheel so as to make 2·25 revs. per hour or 0·450 × 360 = 162° in 12 mins. This gives ample room for the needle to swing. The full ranges of the ammeter can therefore be employed.

The instrument was started at 13 o'cl. on the 1st Aug. and it continued running without interruption until 15·30 on the 24th = 74·5 hours. The dial at starting stood at 00004. At the end of this time it registered 217·4 or recorded 213·4 = 2·86 hourly.

The resistance of the spool is 0·05 ω warm.

Data and Dimensions of a Ring of iron wire for tests of hysteresis under alternating currents.

This ring was formed by winding bare iron wire on a wooden spool with a semicircular trough. The wire is 0·0375 in diameter.
The weight of the ring is 1540 gms. @ 7·7 = 200 c.c.

Its mean ext: diam.	=	15·55	
" " int: "	=	10·5	
" " mean "	=	13·0	incs: 40·8
" " breadth radially	=	5·	
" " " transversely	=	3·85	
" " cross section of iron	=	4·9	by weight 200/40·8

Let $\mathfrak{L}$ = the max: ind: this iron
B = " int: "
N = " no: of turns of wire.
μ = 911
A = 4·9

Then $4.9 \times 911 \times \mathfrak{L} \cdot w = 1.41 \times 10^{10}$ worked on 100 v: alt:
$4465 \times \mathfrak{L} \cdot w = 14.1 \times 10^9$
$\mathfrak{L} w = 3.157 \times 10^6$

for $\mathfrak{L}$	=		
3000	or 3×10^3	w =	1.05×10^3
5000	5×10^3	w =	6.40×10^2
10000	or 1×10^4	w =	3.185×10^2

There ought therefore to be at least 750 turns of wire on the ring.

408 turns of #23 B.W.G. wound on first layer 2.90 Ω 20°C
392 " " " second " 2.784 Ω 20°C
Terminals at 508ft, 608ft, 708ft, + 800ft turns. 5·714
Two secondaries of 50 turns each.

Test. of 2-Kilowatt Transformer 24th July 91.

Weight without clamps 60 lbs.
This transformer was completed at 17 o'cl: on the 24th
The resistance of its primary was 5·57 Ω
" " " secondary " 0·235 Ω @ 23° C.

It was operated at 1000 volts on the primary ext: + 120 on the secondary, with the alternator making 1075 rpm: = 17$\frac{5}{12}$ ~
The transformer lit 40 lamps without difficulty $\mathfrak{f}$ = 900·4
The temperature at 18 o'cl: reached 185° F no load. $\mathfrak{L}$ = 224, 400
" of the room being 83° F. $\mathfrak{L}$ = 4000

There are 391 plates external of the ring type. (68 sq. cms)
447 " internal " " spiral type. (55 sq. cms)

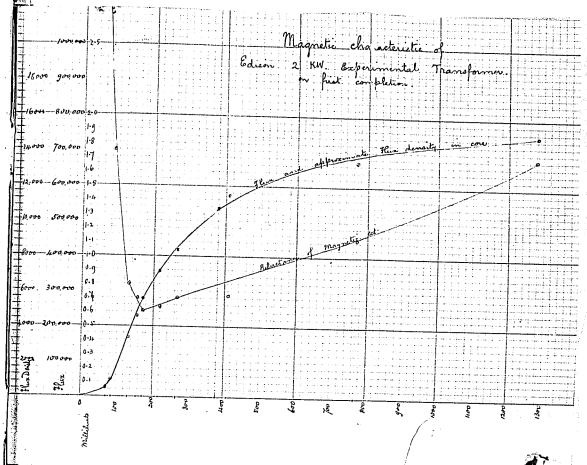
The high temperature quickly reached in the transformer was traced to the large eddy current loss in the face of iron when the horizontal outside rings abut the vertical core plates. The transformer was therefore taken apart, and the outside plates reassembled, after inserting a thin sheet of mica between them and the interior core. This produced a marked improvement.

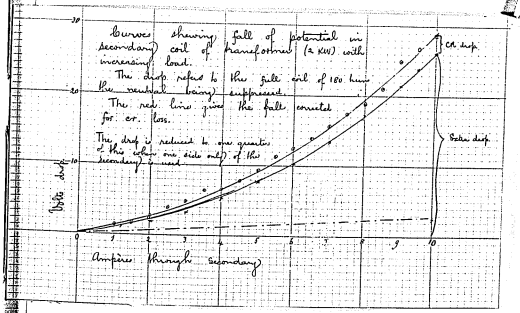
The temperature of the surface after operating 40 lamps for 4 hours was 212° F ext: 230° F int: Room 80° F
The temp: of the surface after operating without load for 4 hours was 200° F ext: 212° F int: Room 80° F

Each plate 0.0153 × 8 = 0.1228 sq. cms.

Interior core 447 × 0.1225 = 54.76 avg 55

Exterior " 391 × 0.1225 = 47.9 + 3.8




Curves showing fall of potential in secondary coil of transformer (2 KW) with increasing load.
The drop noted is the full coil of 100 turns the residual being suppressed.
The red lines give the full curves for cr. loss.
The drop is reduced to one quarter of the value on side coil of the secondary wound
CR drop
Total drop
Volts drop
Amperes through secondary

Magnetic Test of 2 KW. Transformer.

The primary was joined up to the 120 volt mains through resistance and a reversing switch the secondary being connected to the ballistic galvanometer in the usual way.

Source of EMF.	EMF at temp	Capacity	Q	Mean throw	q. per div.	R. of G.
1 C.c. @ 25°C	1.427	2 f	2.854×10^{-7}	182.	1.568×10^{-9}	5350 ω

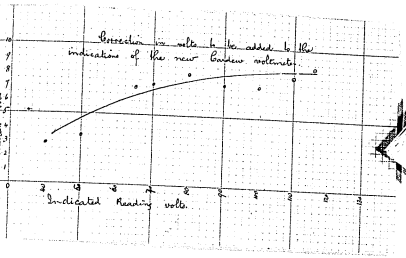
Std. Tan.	Amp. 0.7752	No. of Throws	Mean throw	Res. in cct. with G.	R. of G. cct.	q	φ	B in core	Amp. turns	H	μ	ρ	Sec. turns
0.10505	0.1355 / 0.08142	5	55.8	100,000	105,350	875×10^{-8}	~~29~~ 25,600	4,655 / 533	57	71.6		2.8×10^{-3}	180
0.1243	0.1604 / 0.07636	5	105.2	-	-	16.5	48,280	8,778 / 1006	67.5	84.8		1.757	-
0.1944	0.2508 / 0.1507	5	185.0	200,000	205,350	29.01	165,400	30,080 / 34,460	105.5	132.6		0.802	-
0.2309	0.2979 / 0.1790	4	252.5	-	-	39.59	225,800	41,050 / 47,040	125.3	157.4		0.697	-
0.2540	0.3277 / 0.1967	5	209.8	300,000	305,350	32.9	279,100	50,740 / 58,150	137.8	173.2		0.621	8485
0.3201	0.4129 / 0.3201	4	269.0	-	-	42.19	357,800	65,040 / 74,520	173.8	218.4		0.610	-
0.3889	0.5017 / 0.2442	5	156.6	-	-	24.56	416,600	75,720 / 8,680	211.1	265.3		0.637	90
0.5543	0.7150 / 0.4297	5	201.6	-	-	31.61	536,000	9,744 / 11,170	300.8	378.0		0.705	90
0.6009	0.775 / 0.4654	5	215.2	-	-	33.74	572,300	10,400 / 11,920	325.7	409.3		0.715	-
1.1250	0.8720	5	258.8	-	-	40.58	668,400	12,150 / 13,930	610.5	767.2		1.148	-
1.8807	1.4580	3	282.3	-	-	44.27	751,000	13,650 / 15,650	1021.	1283.		1.708	-

With 1000 eff. volts at 143.3 ~ per sec: the flux = 225,000 or 4500 per sq. cm. The hysteresis at this = 1900 ergs per c.c. There are 3000 c.c. of iron in the transformer so that the hysteresis estimate is 0.57 Watts per cycle = 81.7 Watts. The C²R loss is 62.5 making 144.2 watts at full load neglecting eddy current loss.

Trial of Transformer on the 25th

The plates having been reassembled with mica between the contact faces, the following observations of pressure were made:–

Lamps on + side	Lamps on − side	Voltmeter Weston on	Res. in cct. with voltmeter	Multiplying power	P.D. observed	Calculated P.D.	Drop	P.D. +	P.D. −	Drop
0	0	Series both + −	3000	2.451	98.7	242	0	121	121	0
1	1	-	-	-	98.7	242	0	121	121	0
2	2	-	-	-	98.2	240.7	1.3	120.35	120.35	0.65
3	3				98.0	240.3	1.7	120.15	120.15	0.85
4	4				97.6	239.3	2.7	119.65	119.65	1.35
5	5				97.1	238.0	4.0	119.0	119.0	2.0
6	6	-	-		96.7	237.1	4.9	118.55	118.55	2.45
7	7				96.1	235.6	6.4	117.8	117.8	3.2
8	8				96.0	235.35	6.65	117.68	117.68	3.32
9	9	-		-	95.5	234.1	7.9	117.05	117.05	3.95
10	10				94.9	232.65	9.35	116.33	116.33	4.67
11	11				94.1	230.7	11.3	115.35	115.35	5.66
12	12	-	-	-	93.6	229.15	12.5	114.75	114.75	6.25
13	13				93.0	228.0	14.0	114.0	114.0	7.
14	14				92.3	226.3	15.7	113.15	113.15	7.85
15	15	-	-	-	91.6	224.6	17.4	112.3	112.3	8.7
16	16				91.0	223.1	18.9	111.55	111.55	9.45
17	17	-	-	-	90.1	220.9	21.1	110.45	110.45	9.55
18	18				88.5	217.0	25.0	108.5	108.5	12.5
19	19				87.8	215.2	26.8	107.6	107.6	13.4
20	20				87.0	213.3	28.7	106.65	106.65	14.35
20	0	+	0		121.5	121.5	0.			
20	0	-	-	-	114.0	114.0	7.5			
20	20	-	-	-	108.0	108.0	13.5			
0	20	both	3000	2.451	116.5	116.5	~~5.0~~			
0	0	-	-		98.4	241.3	~~0~~	120.65	120.65	0
20	0	-	-		94.0	230.4	11.6	~~115.7~~		
20	20				86.5	212.1	29.2	~~106.0~~	106.05	14.6
0	0	Ammeter across + − secondary			~~100.5~~	246.3	0			
0	0	- off			98.5	241.5	4.8	123.15	123.15	0
20	0	- across			94.2	230.9	15.4	120.75	120.75	
20	20				57.5	214.5	31.8	107.25	107.25	15.9


Correction in volts to be added to the indications of the new Carlew voltmeter.
Corrections in volts
Indicated Reading volts.

9.

No. of No.
1
2
3
4
5
6
7
8
9

Calibration of New Cavendish voltmeter 27th July 91.

No.	Cavendish Reg.	Weston reading	Difference of Cavendish	Ratio of Weston	Difference Terminals	Temp.	Current	Resistance	Ratio of Cavendish	$\psi_{(t)}$	ψ^{+}	$1+\psi+\psi^{+}$
							0·17703					
1	40	42·9	2·9	10140	10°·10′	0·17933	0·13905	308·5	4·28	0·2966	0·09	1·387
2	50	53·5	3·5	-	12°·30′	0·22169	0·1719	311·2	4·33	0·2992	0·09	1·39
3	65	72	7·0	2070	18°·30′	0·25862	0·2005	337·2	4·33	0·1735	0·3	1·2014
4	70	77·2	7·2	-	15°·0′	0·26795	0·2091	369·1	4·47	0·178	0·032	1·21
5	80	88·0	8·0	-	16°·45′	0·30097	0·23314	377·0	4·58	0·182	0·033	1·215
6	90	97·2	7·2	-	18°·15′	0·32975	0·2556	380·3	4·63	0·182	0·034	1·218
7	100	107·2	7·2	-	20°·05	0·36562	0·2834	378·2	4·61	0·183	0·034	1·218
8	110	115·0 Hamilton	8·0	-	21°·45′	0·39896	0·3093	381·5	4·65	0·1814	0·034	1·218
9	110	118·5	8·5	-								
10	115	123·75	8·75	-	21°·0	0·38376	0·2976	416	4·16			

Correction to be applied to an observed resistance for the effect of a high resistance shunt in reducing it.

Let ψ be a resistance

x " " shunt to ψ but which is large compared with ψ

r " the apparent joint resistance of x and y together.

Then $r = \frac{xy}{x+y} = y - \frac{y^2}{x} + \frac{y^3}{x^2} - \frac{y^4}{x^3} + \text{&c.}$

$= y\left(1 - \frac{y}{x} + \frac{y^2}{x^2} - \frac{y^3}{x^3} + \text{&c}\right)$

Let $\frac{y}{x} = p$ $\quad \therefore r = y\left(1 - p + p^2 - p^3 + p^4 - \text{&c}\right)$

Also $\psi = \frac{rx}{x-r}$ $\quad = r + \frac{r^2}{x} + \frac{r^3}{x^2} + \frac{r^4}{x^3} + \text{&c}$

$= r\left(1 + \frac{r}{x} + \frac{r^2}{x^2} + \frac{r^3}{x^3} + \text{&c}\right)$

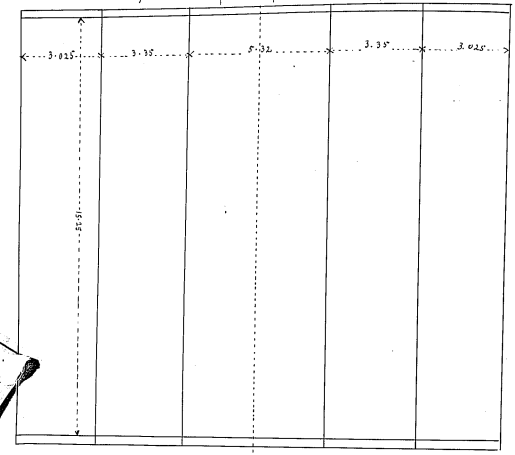
Let $\frac{r}{x} = q$ $\quad \therefore \psi = r\left(1 + q + q^2 + q^3 + \right)$

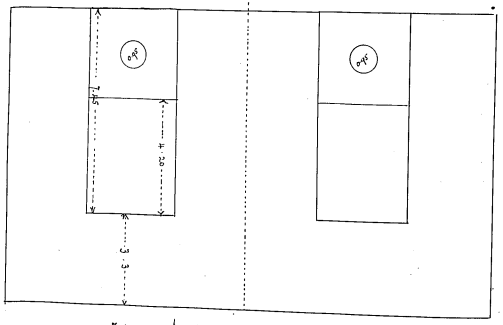
Tests of 2 K.W. Transformer 27th July 91.

90 turns of 4·19 S.W.G. were looped on round the centre of one side on the ring. This winding is called C in the following table.

No. of Obs.	Cavendish Reg.	Remarks	Primary current + voltage	A Turns	B Load	A volts	B volts	C volts	A diff	B diff	C diff	Ratio $\frac{B}{A}$
1	91	98	4000 9·41	20 λ	20 λ	106·5	105·5	110	15·5	16·0	10	
2				15	15	110·5	110	112	11·5	11·5	8	
3				10	10	115	114·5	115	7	7	5	
4				5	5	119	118·5	118	3	3	2	
5				0	0	122	121·5	120	0	0	0	
6				20	0	115	116·8	116	7	4·7	4	
7				0	20	115·6	111·9	116	6·4	6·6	4	0·606
8				40			115	-	4·75			
9				40			105·25	110	14·25		10	0·615

Full size Plan of Core of 15 Kt T.H Transformer 2E.





Full size. Section of Core 15·Kt 2E T.H Tr.

Tests of 2 K.W. Transformer continued 27th July 91. (52)

A new coil of about 90 turns was wound on the primary coil. it was used as an exploring secondary and marked D.

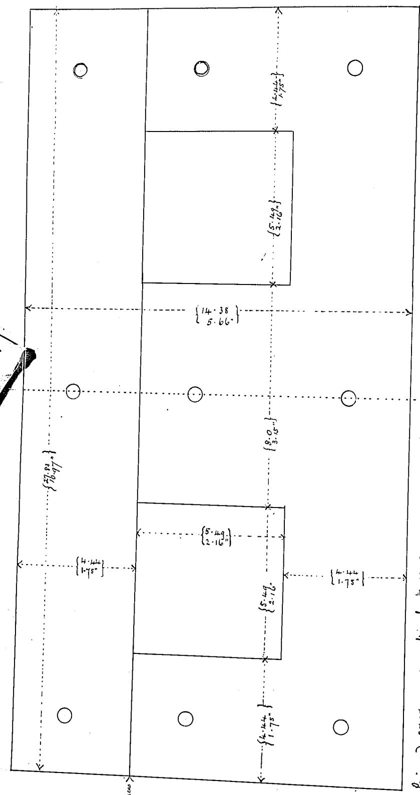
No of Obs	A load	A volts	A drop	B load	B volts	B drop	D load	D volts	D drop	Ratio $\frac{D}{B+D}$
1	0	121·5	0	0	121·5	0	0	119	0	
2	40 λ	106·75	14·75	40 0	108	13·5	0	111·75	7·5	0·555
3	Fifty plates were taken off each end or 100 in all and readings repeated									
3	0	120·5	0	0	120·5	0	0	118	0	
4	40 λ	104	16·5	0	105·5	15	0	109·5	8·5	0·567
	Fifty plates more were taken off each end or 200 in all and readings repeated									
5	0	124	0	0	124	0	0	121	0	
6	40 λ	104·25	19·75	0	107·25	16·75	0	115·75	7·75	0·433

Data and Description of 2E T. H. 15·Kt. transformer. 27th July 91.

Weight of shell. 42 lbs. Weight of transformer whole 86 lbs.
Extreme external dimensions of shell
Weight of transformer proper 44 lbs.
The core of this transformer is represented on the opposite page:-
Thickness of core plates 0·014".
Primary voltage 1000.
Secondary " 50 or 100 according to connections in free bnc.
Primary wire 635 turns of # 25 B.W.G. 0·020".
Secondary " 64 " " # 15 B.W.G 0·072". (32 turns in each coil)
Weight of primary wire 640 grms.?
" secondary " 760 "
Res: of primary " coil 33Ω
" " secondary " " 0·09Ω two in parallel = 0·18Ω in separately.
Weight of iron core and fittings 42·5 lbs.
T. H. Frequency 125 ~
Core area 15·25 × 2·66 = 40·57 × 2 = 81·14 sq·cms.
Winding space area 44·7 sq·cms.

Section of transformer full size.

Thickness 8.0.
as constructed 7.75



Take 8 cm

[illegible] 1 KILOWATT ALTERNATING CURRENT TRANSFORMER

[illegible] effective voltage 1000
[illegible] effective current 1.05 amperes.
[illegible] one kilowatt or 20 50-watt 16 c.p. lamps.
Secondary effective voltage [illegible] volts on 3-wire or 1[illegible]0 on side.
Secondary effective current [illegible] amperes at full load.
[illegible] without shell [illegible] 1/2 lbs.
W[illegible] in shell complete 110 lbs.
Primary [illegible] lbs. of [illegible] wire 0.0[illegible]" dec. to 0.0[illegible] in [illegible]00 turns.
Secondary [illegible] lbs. of [illegible] wire 0.0[illegible]" dec. to 0.0[illegible]" in 1[illegible] turns, brought out [illegible] turn for neutral connection.
[illegible] of copper wire 11.[illegible] lbs. or 0.5[illegible] lb. per lamp.
Iron plates of [illegible] (or [illegible]) assembled [illegible] paper.
[illegible] of finished plates as follows:-
Total [illegible] 10.[illegible]"
[illegible]
[illegible] of core [illegible].15" depth of core [illegible].16"
[illegible] 1.[illegible]"
[illegible] of sides 1.75"
[illegible] of transformer plates assembled 3.05"
[illegible] holes in box and [illegible] in lid.
[illegible] weight of iron plates [illegible] lbs.
Resistance of primary 7.[illegible] ohms cool [illegible] ohms hot.
Resistance of secondary 0.43 ohms cold. 0.[illegible]2 ohms hot.
Drop in primary at full load [illegible] volts.
Drop in secondary at full load [illegible] volts or 1.[illegible] on side.
[illegible] drop in secondary due to resistance [illegible] volts on side.
[illegible] drop observed on continuous full load [illegible] volts on si[illegible]
Extra drop in transformer due to leakage 1.[illegible] volts.
Temperature elevation at full load as follows:-
Operated on 20 lamps continuously for 1[illegible] hours in shell.
Elevation of temperature of shell surface above air [illegible] C.
Elevation of temperature of transformer coils [illegible] C. [illegible]
[illegible] of shell 1[illegible]" over clamps [illegible]" hot
Internal diameter of shell [illegible]".
Length of shell internally 1[illegible]"
Length externally 15"
Depth of fuse chamber 1 1/[illegible]"
[illegible] insulation between primary and secondary coils and also between coils and iron frame.
Secondary coil at bottom of box and primary coil above next lid.
Surface of lid and of box on which lid fits, planed true after riveting plates in order to insure good contact.
Surfaces on which clamps hold also planed true to insure even pressure on lid.

Dimensions for a Rectangular Plate Transformer

Working 64 sq. cms. for core area as below. The central core will be square. Allow 30 sq. cms. for cross section of winding space (5.48").

width 27.83 (10.97")
breadth 8.0 (3.15")
depth 14.38 (5.66")
area of upper and lower surfaces each 222.7 "
area of long side surfaces " 400.2 − 60.2 = 340.0
" short " " " 115.0
total surface of iron 13.55 sq. cms.
volume of iron 27.83 × 8.0 × 14.38 − 5.48 × 5.48 × 16.0 = 3202 − 1482 = 2720 cc.
" winding space 1482 c.c.
Weight of iron 21.32 kgms. = 47 lbs. (supposing) no waste space.
Net " " 19.2 " = 42.5 lbs.
Length of magnetic circuit 37 cms.
Gross section of winding space 30.14 sq. cms.
Gross section occupied by 700 turns of # 19 B.W.G. 0.052" d.c.c. & 0.053" 12.7
" " " 180 " # 14 B.W.G. 0.083" " " 0.096" 10.7
" " " 180 " # 13 " 0.095" " " 0.104" 13.55
Total section occupied when using # 13 B.W.G. 26.25 leaving 4 sq. cms. for ins. and imperfect winding.
Total section occupied when using # 14 B.W.G. 23.4 " 6.74 sq. cms. for ins.

The secondary coil will be at the bottom of the box.
The winding will be square. Mean side 13.5 mean turn 54"
Length of primary 37500 = 12.40'
" secondary 9720 = 3.2'0
Resistance of primary coil @ 20° C. 7.26 Ω @ 60° C. 8.30 Ω @ 100° C. 9.35 Ω
" secondary # 14 B.W.G. " 0.491 Ω 0.560 Ω 0.634 Ω
Current at full load in secondary 10
Drop in " " " 5.6 volts 2.8 volts on each side.
Current " " " primary 2.857
Drop " " " 20 volts.

Mean length of magnetic circuit 37 cms.
As constructed the winding was Primary 700 turns # 20 B.W.G. 0.035" d.c.c. & 0.0375". Resistance 8.7 Ω @ 27° C.
Secondary 180 turns of # 14 B.W.G. 0.080" d.c.c. & 0.099".
Resistance @ 27° C. 0.1461 Ω.

With 10 amp. in the secondary ect: the drop should be 5.0 volts (worm)
" 3 " " primary " " " 30 volts "
reduced in ratio $\left(\frac{180}{700}\right)^2 = (.257)^2 = 0.0664 \times 20 = 1.33$ volts.
Total drop 12.7 volts or 6.35 on each side. for 10 amp. & 40 lamps
" 6.7 " " 3.35 " " " 5 " " 20 "

Inductance of primary in air 1000/00 108.65 Ω 0.625 ℧ = 67.92 h.
" secondary " " 1000/0 20.57 Ω 0.225 ℧ = 4.63 "
Ratio 14.67 Ratio of turns 3.89 Squared 15.13

Mutual inductance when coils superposed in air
1100/00 108.65 0.66 ℧
$\frac{1}{2\pi}(71.7 - 67.92) = \frac{1}{6.28}(3.78) = .3437$ h.

See p. 65 :—

1 KWT Motor.

The 500-volt armature is wound with 15 layers of 10 turns each and 7 extra turns above making 157 turns in all to one groove = 4452 wire.

The 120-volt armature is wound with 7 layers of 5 turns each and 2 extra turns above making 37 turns in all to one groove = 1332 wire.

Experimental field 6 layers of 80 turns each = 480 turns. #16 B&S wire

Particulars of Preliminary Trial with the 1 KWT motor. (54)

30th July.

The motor weighs 108 lbs. without pulley. The 500-volt armature was tested, with 3 amperes exciting the field.

The speed on 120 volts at armature terminal was 430 rpm with a current of 0·25 ƒ = 31 Watts absorbed or 4·2 Watts per rev. per sec (4·2 Joules per rev)

The speed with 500 volts at armature terminals was 1700 rpm. with a current of 0·15 ƒ = 75 Watts absorbed or 2·65 Joules per rev.

When belted to the 1 HP. Peart motor driven as a dynamo, thus latter separately excited and operating 12 lamps at about 120 volts per lamp the current absorbed by the motor was 2·27 ƒ at 500 volts = 1135 Watts.

There was very little sparking at the brushes on this load, and the only part of the armature that developed any heat was the tooth surface, and this was not serious. The field remained quite cool.

Data of the variation in candle power of lamps at different pressures. 31st July 91.

One low volt lamp gave 20 cp @ 67 v.

Another . . . 23 - @ 69 v. = 3 cp. for 2 v. 1 cp. for ⅔ v. = 1%
20 - @ 67·5 v.

Ordinary high . . 23·5 - @ 69·5 = 3·5 cp for 2 v. 1 cp for ⅔ v. = 0·85%
20 - 120 v
22 - 122 v = 2 cp for 2 v. 1 . . 1 = 0·83 ƒ

Character of lamp	Voltage	Δ v	Δ cp	Δv / Δcp	Δcp / Δv	% variation of watts for 1% cp	% change of cp for 1% voltage	% change of voltage for 1% cp	Absolute change of voltage
Low volt	67	+ 69·2	3·25	0·615	1·625	0·92	1·08	1·84	1·23
High volt	120	+ 122·2	2	1·0	1·0	0·833	1·2	1·67	2·0

Measurement of weight of chain in Edison Deposit meter of 3-wire construction. 1st August. 91

Length of the chain = 30·445 cms nearly 12".
Mass . . . = 0·5885 gms.
= 19·33 mgms per cm.
1 centigramme of chain represents 0·5173 cms or 0·2037".

A phosphor-bronze wire chain the wire see f. 75 being 0.02 on completion measured 29.15 cms, and weighed 0.6307 gms. or 21.64 mgms per cm. ∴ 1 gm. of chain represents 0·4621 cm. = 0·192".

Apr. 2, 1892.

Report of test on 200 K.W. Direct Driven Dynamos at the 26th Street Station of the Edison Electric Illuminating Co., N. Y.

On arriving at the station on the 28th of March we found both machines in readiness to test. Before starting I determined the insulation resistance of each armature to ground and found dynamo #1 to measure 130,000 ohms and dynamo #2 72,000 ohms. We then started both machines up and obtained the potential developed in each pole, as follows:-

Dynamo #1.		Dynamo #2.	
Pole #1	108 volts	Pole #1	108 volts
" 2	108 "	" 2	108 "
" 3	108 "	" 3	110 "
" 4	110 "	" 4	108 "
" 5	110 "	" 5	108 "
" 6	110 "	" 6	108 "
" 7	110 "	" 7	109 "
" 8	110 "	" 8	108 "
" 9	112 "	" 9	108 "
" 10	112 "	" 10	110 "
" 11	112 "	" 11	110 "
" 12	111 "	" 12	109 "
" 13	109 "	" 13	108 "
" 14	109 "	" 14	108 "

Number 1 dynamo was then started up and run on load varying from 900 to 1300 amperes until late into the evening, #2 dynamo being run during this time with field on and brushes up, in order to gradually heat it up and remove whatever small traces of moisture it might contain.

On the 29th of March we started the machines up for a 48 hour ~~test~~ run, each carrying 1300 amperes and 130 volts, but we were obliged to shut down after a 7 hour run on account of the engine being disabled, and it was not until the 30th of March that we were again able to start. The test was then started at 10 A.M. and both dynamos run on loads varying from 1000 to 1300 amperes until 6 P.M., when we were then able to put 1333 amperes on both machines. At 1 A.M. on the 31st of March the load of the station dropped, however, so that we were only able to carry 500 amperes on each machine until 8 A.M. when the load again increased to 1333 amperes, and we continued to run the machines on this load until we shut down at noon, at which time the temperature of the armatures, taken while running by means of thermometers placed in the

neutral point and as close to the armature as possible without striking, indicated that the ultimate temperature had been reached. When shut down thermometers were placed on the bands of the armature and another thermometer placed on the field magnets, and the temperatures were taken with the following results:-

Room		75° Fahr.
Dynamo #1		165° Fahr.
Magnets		110° Fahr.
Dynamo #2,	Armature	164° Fahr.
	Magnets	112° Fahr.
Insulation	magnets	1 megohm.

The insulation to base on armature #1 was 145,000 ohms, and on dynamo #2 was 50,000 ohms.

The saturation test was then taken on dynamo #1 and the curve plotted on the accompanying sheet is marked #1.

The engine after being tightened up was again started and both dynamos were brought up to full load of 1333 amperes, which load was gradually increased at 5 P.M. to 1400 amperes on dynamo #1 and 1460 amperes on dynamo #2. At 1 A.M. the load fell off to 600 amperes on each dynamo, and it was not until 8 A.M. that the load could be brought up to 1333 amperes, and so the dynamos continued to run until 11 A.M., so making a 48 hour test lacking 3 hours. The temperature was again taken with the following results:-

Room		76°
Dynamo #1,	Armature	159°
	Magnets	113°
Dynamo #2,	Armature	148°
	Magnets	113°
Insulation	#1 dynamo	72,000 ohms.
"	#2 "	18,000 ohms.

A set of readings showing the voltage on the field magnets with different loads of machine were then taken. This curve is plotted on a attached sheet and is marked Curve #2. The maximum increase of temperature of armature #1 was 90° Fahr. or 50°C.

ditto	#2	"	89° "	or 49.5°C.
ditto	#1	"	35° "	or 19.5° C.
ditto	#2	"	37° "	or 20.5° C.

A series of indicated diagrams were then taken on the engine with dynamo at different loads, copies of which are attached

Apr. 3, 1903.

Report of test on 200 K.W. Direct Driven Dynamos at the

28th Street Station of the Edison Electric Illuminating Co., N. Y.

On arriving at the station on the 28th of March we found both machines in readiness to test. Before starting I determined the insulation resistance of each armature to ground and found dynamo #1 to measure 130,000 ohms and dynamo #2 72,000 ohms. We then started both machines up and obtained the potential developed in each pole, as follows:-

Dynamo #1.		Dynamo #2.	
Pole #1	108 volts	Pole #1	108 volts
" 2	" 108	" 2	" 108
" 3	" 108	" 3	" 110
" 4	" 110	" 4	" 108
" 5	" 110	" 5	" 108
" 6	" 110	" 6	" 108
" 7	" 110	" 7	" 109
" 8	" 110	" 8	" 108
" 9	" 112	" 9	" 108
" 10	" 112	" 10	" 110
" 11	" 112	" 11	" 110
" 12	" 111	" 12	" 109
" 13	" 109	" 13	" 108
" 14	" 109	" 14	" 108

Number 1 dynamo was then started up and run on load varying from 1200 to 1300 amperes and it was not until late in the evening, #2 dynamo being run during this time with a field on and brushes up, in order to practically heat it up and remove whatever small traces of moisture it might contain.

On the 29th of March we started the machine up for a 48 hour ~~test~~ run, each carrying 1300 amperes and 130 volts, but we were obliged to shut down after a 7 hour run on account of the engine being disabled, and it was not until the 30th of March that we were again able to start. The test was then started at 10 A.M. and both dynamos run on loads varying from 1000 to 1300 amperes until 8 P.M., when we were then able to put 1333 amperes on both machines. At 1 A.M. on the 31st of March the load of the station dropped, however, so that we were only able to carry 800 amperes on each machine until 8 A.M. when the load again increased to 1333 amperes, and we continued to run the machines on this load until we shut down at noon, at which time the temperature of the armatures, taken while running by means of thermometers placed in the

Load	Volts.	Amps.	Watts	H.P. from cards	Efficiency Plant
Friction	125	----	----	131.75	----
Half load #1 dyn.	125	700	87,500	303	39%
Full load #1 Dyn.	125	1333	167,000	380	58 3/4%
3/4 load (#1	130	875	114,000)		
(#2	129	1050	136,000)	455	73 1/2%
Full load(#1	128	1400)			
(#2	128	1400)	360,000	609	79%

The general performance of the dynamos was excellant. There was no sign of sparking on any of the brushes and 1/3 load could be thrown off of each without moving the brushes. The change in lead from no load to full load was nine bars. If load be thrown off the dynamos and the brushes be not moved at the same time, the sparking which results is quite moderate, there being no long flashes and arcs which are usually seen in bi-polar machines of large output when load is thrown off. On Thursday night a 32 armature, which was running in parallel with one of these machines, burned out, and for a length of time of five minutes from 1700 to 1800 amperes were thrown on the machines, and they carried it without difficulty, there being no sparking observable.

The brush raising device on Dynamo #1 still works with some difficulty, but the device on #2 works satisfactorily. There is also a certain amount of lost motion between the worm and sector, which operate the brush moving device. Crane intends to rectify both of these faults if possible, but it is probable that we will have to send them a new worm before the trouble can be fully done away with. Both Mess. Smith and Van Vleck seemed ~~not~~ entirely pleased with the ~~worst~~ performance of the plant, and had no adverse comments to make on its running, etc.

The engine used in connection with these 200 K.W. dynamos was the Van Vleck Disconnective Triple Expansion Non-Condensing engine. It is fitted with the usual form of Joy valve gear. The diameters of the cylinders are 18", 27" and 40", and the length of stroke is 30". It will be seen by an inspection of the cards that at full load on the dynamos the engine is doing about all it is able. Attached are five blue prints of cards taken at various loads.

Yours respectfully,

A. F. J. Ehrn.

temperatures were taken at the following tests:-

Room	75° Fahr.
Dynamo #1	185° Fahr.
Magnets	110° Fahr.
Dynamo #2,	Armature 166° Fahr.
	Magnets 112° Fahr.

Insulation magnets 1 megohm.

The insulation to base on armature #1 was 145,000 ohms, and on dynamo #2 was 80,000 ohms.

The armature test was also taken on dynamo #1 and the curve plotted on the accompanying sheet is marked #1.

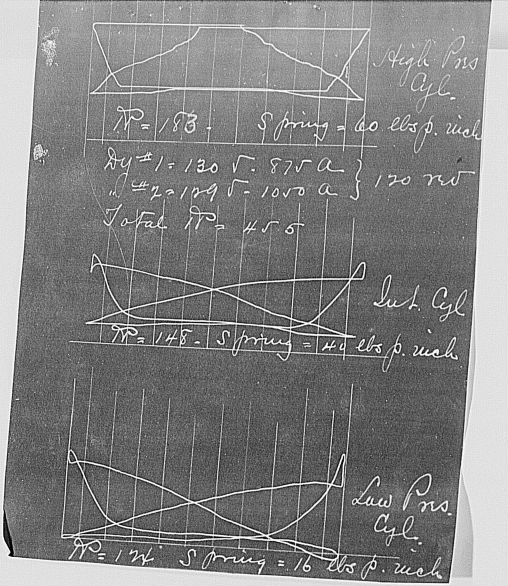
The engine after being tightened up was again started and both dynamos were brought up to full load of 1333 amperes, which load was gradually increased at 5 P.M. to 1400 amperes on dynamo #1 and 1400 amperes on dynamo #2. At 7 P.M. the load was not up till 8 P.M. to 1333 amperes, so the load could be brought up to 1333 amperes, and so the dynamos continued to run until 11 P.M., so making a 48 hour test, and fell off to 800 amperes on each dynamo, and it was not up till 8 P.M. looking & house. The temperature was again taken with the following result:-

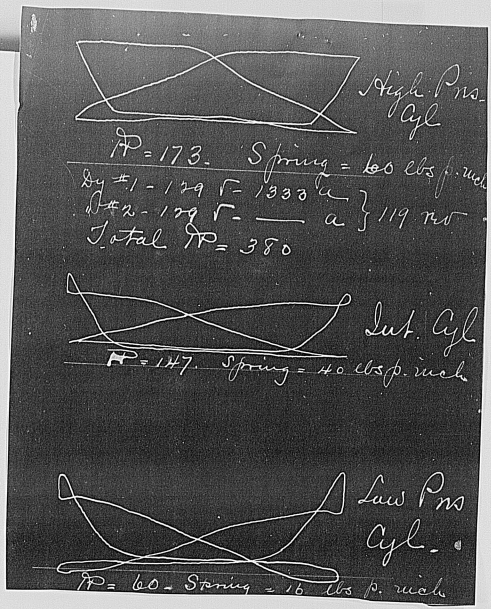
Room	76°
Dynamo #1,	Armature 158°
	Magnets 118°
Dynamo #2,	Armature 148°
	Magnets 118°

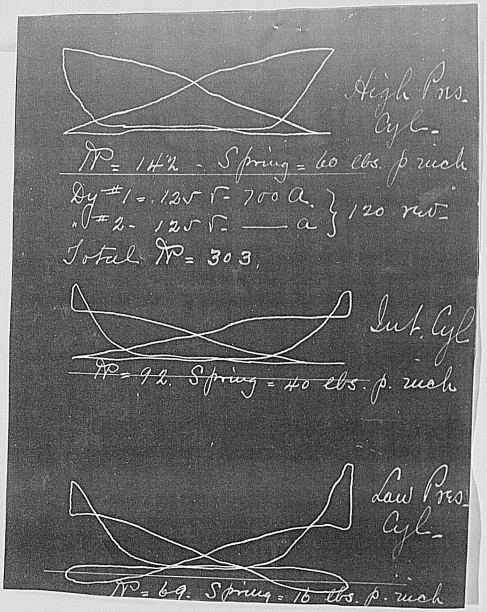
Insulation #1 dynamo 75,000 ohms.
" #2 " 18,000 ohms.

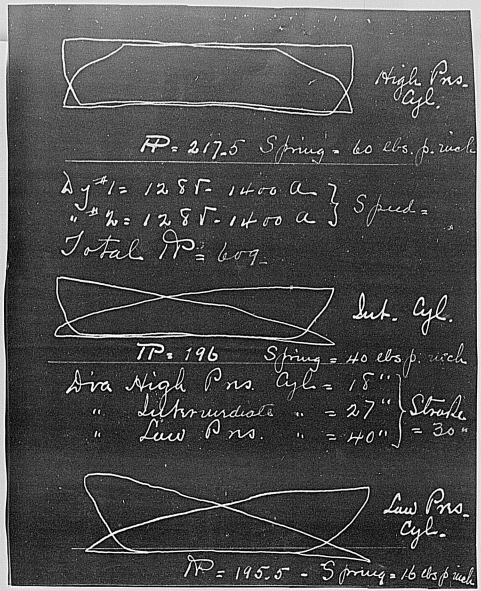
A set of readings showing the voltage on the field magnets with different loads of monitors were then taken. This curve is plotted on a detached sheet and is marked Curve #2. The maximum increase of temperature of armature #1 was 80° Fahr. or 62.2° C.
" " " #2 " 80° " or 62.2° C.
" " " #1 " 32° " or 17.8° C.
" " " #2 " 32° " or 20.2° C.

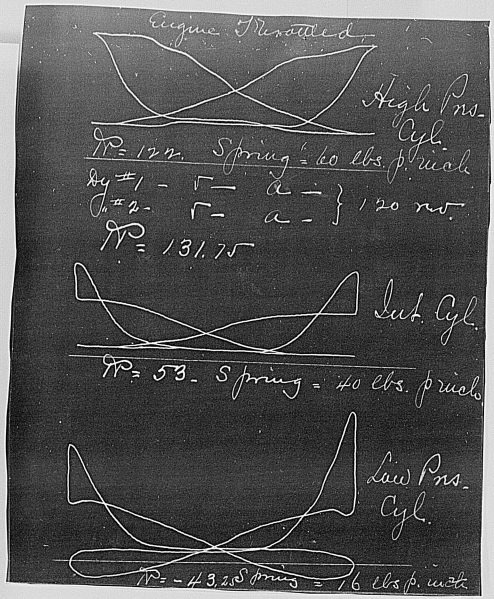
A series of indicated diagrams were then taken on the engine at dynamo at different loads, copies of which are attached


High Pres Cyl.
MP = 183. Spring = 60 lbs p. inch
Dy #1 = 130 √ - 875 a
" #2 = 179 √ - 1070 a } 170 rev
Total MP = 455
Int. Cyl
MP = 148. Spring = 40 lbs p. inch
Low Pres. Cyl.
MP = 174. Spring = 16 lbs p. inch


High Pres. Cyl
MP = 173. Spring = 60 lbs p. inch
Dy #1 - 129 √ - 1333 a
" #2 - 179 √ - —— a } 119 rev
Total MP = 380
Int. Cyl
MP = 147. Spring = 40 lbs p. inch
Low Pres Cyl.
MP = 60. Spring = 16 lbs p. inch


High Pres. Cyl.
MP = 142 - Spring = 60 lbs. p. inch
Dy #1 = .125 √ - 700 a.
" #2 - 125 √ - — a } 120 rev.
Total MP = 303.
Int. Cyl.
MP = 92. Spring = 40 lbs. p. inch
Low Pres. Cyl.
MP = 69. Spring = 16 lbs. p. inch


High Pres. Cyl.
MP = 217.5 Spring = 60 lbs. p. inch
Dy #1 = 125 √ - 1400 a. } Speed =
" #2 = 125 √ - 1400 a. }
Total MP = 609.
Int. Cyl.
MP = 196 Spring = 40 lbs. p. inch
Dia High Pres. Cyl. = 15" } Stroke = 30"
" Intermediate " = 27" }
" Low Pres. " = 40" }
Low Pres. Cyl.
MP = 195.5 - Spring = 16 lbs. p. inch


Engine Reversed
High Pns. Cyl.
P = 122. Spring = 60 lbs. p. inch
Dy #1 - 120 rev.
Dy #2 -
P = 131.75
Int. Cyl.
P = 53. Spring = 40 lbs. p. inch
Low Pns. Cyl.
P = 43.25 Spring = 16 lbs. p. inch

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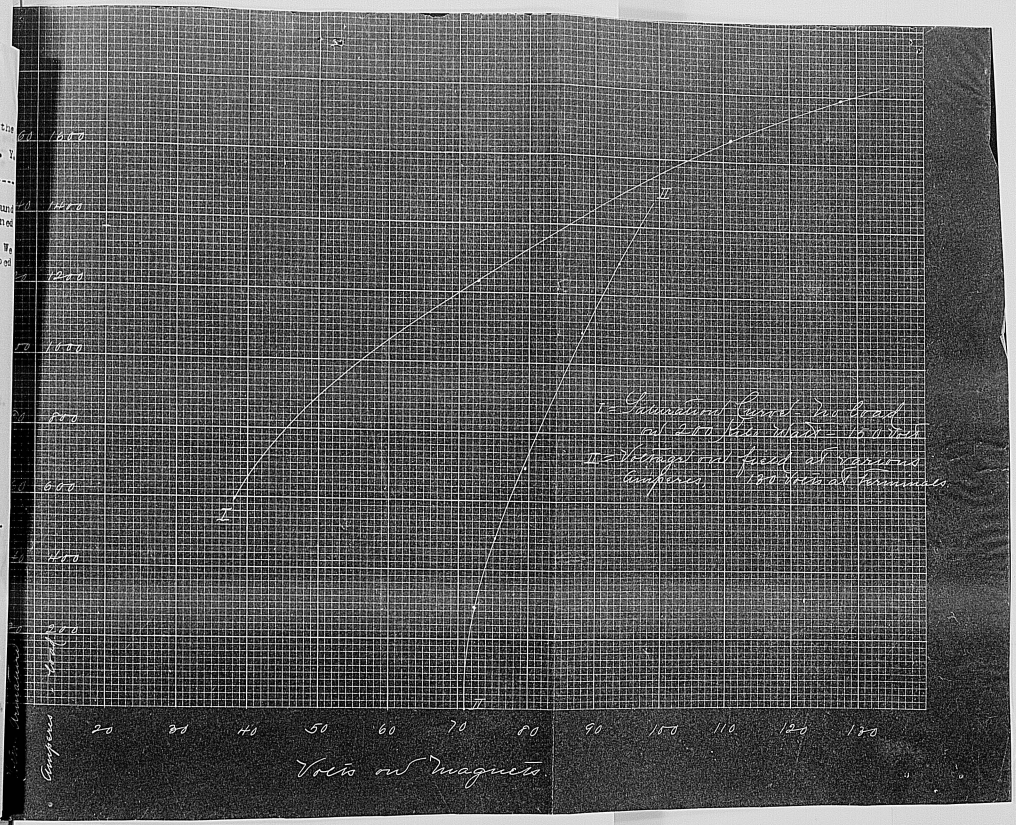


Data of new 200 KW. Multipolar dynamo with cast steel field magnets, designed by Schenectady Works. 27th June, 91.

Watts 200,000 Watts
Voltage 150 at machine terminals
Current 1333 amperes
Speed 120 revs: per min: 2 revs: per second, 43.5 feet per sec: 2610' per min: 1326 lines peripherally.
Poles 4
Nominal diameter of armature 83.5"
Lines on armature 1008
Current density, amperes per cms: of circumference 145
Gross sectional area of box 91,000 circ. mils
Section per ampere 955 circ. mils.
Intensity in air gap 5200
Total useful flux 5.45×10^7 lines.
Total E.M.F generated 157 volts
Breadth of armature body 17.25".
Radial depth - - - 4".
Section of body, no paper insulation 69 sq: in:
Intensity in full section of armature 8750 c.c.s.
- bolt hole sections 10,600 - -
Diameter of cores 13".
Section of keepers $16.5" \times 4\ 5/16"$
Intensity in cores 12,000 C.G.S.
- - keepers 11,000 - -
Armature resistance hot 0.0024 ω. $\times 14 = .0336$ ω each cont:
Watts lost in armature at full load 4280
- - - per sq: in: of rad: surf: 0.396
Rise of temp: on armature 31° C.
Ampere turns on each core 7350
Current in shunt field 24.4 amp. -
Resistance of shunt hot 5.23 ω.
Watts per sq: in: on field: 0.25.
Rise of temp: on field 20° C.
Total weight of wire on field 1596 lbs.
Size of wire on field #5 B+S.
Watts lost in field 3108
Watts lost in res: box 550
Drop across shunt 127.4 volts
Drop across box 22.6 - -
Efficiency Watts lost in armature conductors hot 4280
- - - field - 3108
- - - box - 550
Hysteresis 2170
10108

Electrical efficiency 200,000 / 210,108 = 0.952

Total weight of dynamo complete 27,170 lbs: giving 7.36 watts per lb:

Siemens & Halske Actiengesellschaft. Berlin.

Belt driven Multipolar Dynamos

Output in Kilowatts	Volts	Amps.	Revs.	Poles.	Weight lbs.	Watts per lb.
1.65	110	15	1640	2	570	2.89
3.3	110	30	1400	2	970	3.46
6.6	110	60	1250	2	1400	4.71
8.25	110	75	970	2	1650	5.16
11	110	100	950	2	2500	4.4
18	120	150	920	4	3740	4.81
24	120	200	820	4	4650	5.16
36	120	300	750	4	5200	6.92
54	120	450	600	4	7700	7.01
72	120	600	510	6	9700	7.42

Edison General Electric Company's

Belt driven Multipolar Dynamos

Output in Kilowatts	Volts	Amps.	Revs.	Poles.	Weight lbs.	Watts per lb.
10	125	80	1250	4	1370	7.3
15	125	120	1150	4		
20	125	160	1100	4		
30	125	240	1000	4	3300	9.09
40	125	320	800	4	4550	8.25
50	125	400	700	4	5500	9.09

2 pole Standard Dynamos

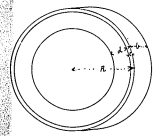
Output in Kilowatts	Speed	Weight lbs.	Watts per lb.
10	1600	1470	6.8
15	1500	2130	7.04
20	1460	2850	6.94
30	1200	4320	6.91
40	1000	6500	5.88
50	700	9790	5.11

Watts per lb	Edison Simens Edison Bell Multipolar direct Dynamos. Kopper of end Iron Cores of Steel. Output in Watts	Volts	Amps	Speed	Number of Poles	Weight complete in lbs	Tilt-che Fleischer Multipolar direct Dynamos All Wrought Iron. Output in Watts	Volts	Amps	Speed	Number Poles	Weight complete in lbs	Watts per lb.
3.13	25	150	166.6	300	4	5000							
							32	160	200	400	11	5250	6.06
							45	160	300	140	5	5500	5.46
4.014	50	150	333.3	240	6	12,350							
4.21	100	150	666.6	172	8	23775							
							180	150	1200	100	12	20,246	8.89
6.83	200	150	1333.3	120	14	29250							

Analysis of the Standard Dynamo Machine of the E.G.E.C.

Volts	Amps	Watts	e^2	r hot	e^2/r	m	Weight complete lbs.	Weight complete kgms.	Watts per lb.	Watts per kgm.	Speed r.p.s.
110	45.45	500	12100	4.24	2820	0.08773	90	5.5	5.5		40
110	6.818	750	"				120	6.25	6.25		40
110	13.64	1500	"	1.052	11,504	0.16304	270	5.5	5.5		35
125	24.0	3000	15625	0.427	36,600	0.082	550		5.45		31.6
"	49.0	6000	"	0.150	104,200	0.05776	820		7.23		30
"	68.	8500	"	0.0878	178,000	0.04775	1090		7.80		28.3
"	96	12,000	"	0.0549	284,600	0.04217	1470		8.16		26.6
"	120	15,000	"	0.0413	378,300	0.03965	2130		7.04		25
"	160	20,000	"	0.0258	605,800	0.0330	2880		6.94		23.3
"	200	25,000	"	0.02158	724,600	0.03445	3570		7.00		21.6
"	240	30,000	"	0.01394	1,121,000	0.0268	4340		6.91		20.0
"	300	45,000	"	0.01162	1,345,000	0.03346	6800		6.62		16.6
"	480	60,000	"	0.01162	1,345,000	0.04446	9790		6.13		11.6
140	714.3	100,000	19600	0.00865	2,947,000	0.0339	16,200		6.17		10.83
"	1250	175,000	"	0.003233	6,027,000	0.02904	31,790		5.5		7.5
150	670	100,000	22,500	0.00566	3,978,000	0.02514	14,400		6.94		2.86
"	1333	200,000	"	0.00240	9,375,000	0.02134	27,170		7.36		2.0

On the relations between the Power of a multipolar gramme-ring dynamo and its dimensions. 2nd Aug. 91.



Let e = the emf generated by the machine.
r = its total armature resistance.
v = the total volume of copper conductor
c = " depth of copper on the surface
b = " breadth of the armature body
d = " radial depth - - -
R = ext: radius of armature.
Π = length of one turn of conductor
ρ = resistivity of the copper
p = number of poles
n = " " revs: per second.
ω = " " " " round.
φ = flux through each pole entering armature.
Φ = mean flux density in armature
S = bd - cross section of armature
W = Power of machine
V = Volume of armature body.
m = coefficient of armature drop in emf.
K = Surface velocity

Then total emf = $p\varphi n\omega$

effective emf = $\varphi n\omega$

total res: of arm = $\frac{\Pi^2\omega^2\rho}{v}$ if section of conductor uniform

effective res. r = $\frac{\Pi^2\omega^2\rho}{v\,p^2}$

$$W = me^2/r = \frac{m\,p^2\Phi^2\varphi^2 n^2\omega^2}{\Pi^2 p^2\omega^2}\cdot cbp^2 = \frac{mcp^2n^2\varphi^2bp^2}{\rho\Pi^2}$$

$$= 4m\frac{R^2n^2}{\rho}cbp^2\frac{S^2}{\Pi^2}$$

If $d = \mu b$ $\frac{S}{\Pi} = \frac{b}{2}\left(\frac{\mu}{1+\mu}\right)$ $+\frac{S^2}{\Pi^2} = \frac{b^2}{4}\left(\frac{\mu}{1+\mu}\right)^2$ for $\mu = \frac{b}{16}$

$$= \frac{m\,R^2n^2\varphi^2p^2\mu S}{\rho(1+\mu)^2}$$

$$= \frac{m\,R^2\kappa^2p^2cb}{2\,\pi^2R^2\rho}\left(\frac{\mu}{1+\mu}\right)V \text{ nearly.}$$

$$= \frac{m\,R^2\kappa^2p^2cb^2}{\pi R\rho}\frac{\mu}{1+\mu}$$

The Power of a multipolar gramme ring dynamo increases with the square of the peripheral velocity, the square of the number of poles the square of the magnetisation, the end directly as the the thickness depth of copper, inversely as the radius and resistivity, but as the cube of the breadth of armature body).

Test No.	P.D. at armature	Brush	Ampres	Energy in armt.	No. of turns	Drop in armt.	Energy lost in armt.	Effect	Speed of armt. r.p.m.	Armt. cpr.	EMF in armt.
	500		0·85	75		3·3	0·5	74·5	1700	28·3	478·7
1	508	0·051	0·263	133·6	22·0	5·79	1·52	132·1	1680	28	502·2
2	496	0·078	0·403	199·9	"	8·87	3·58	196·3	1680	28	487·1
3	"	0·119	0·611	304·6	"	13·51	8·3	296·3	1680	29	482·5
4	502	0·161	0·8305	417·	"	18·28	15·19	402·8	1640	27·3	483·7
5	504	0·2464	1·259	634·3	"	27·7	34·9	599·6	1610	26·93	476·3
6	"	0·341	1·760	887·	"	38·7	68·1	819·9	1580	26·3	465·3
7	"	0·419	2·162	1090	"	47·5	102·6	987·4	1570	26·16	456·5
8	"	0·457	2·359	1189	23·0	52·4	127·9	1061·1	1565	26·08	449·8
9	496	0·429	2·214	1098	24·7	57·25	126·8	971·2	1560	26·0	438·7
10	496				24·7						

Test of Edison 1 H.P. Motor 500-volt Arm: S.E. Field

(58)

3rd Aug. 91

The motor was floated in the tank, and connected by flexible coupling to the Perret 1 H.P. motor operated as a dynamo with sep: exc: field.

EMF per No. per Sec.	Balance	Moment	6165 × Moment	Energy delivered	Friction	Elect: eff: of armt.	Commercial eff: of armt.	Current in field	Energy in field	Condition of Load.
17·55										
17·90	200 @ 5	1000	0·6165×10³	17·	115·1					Light
17·4	200 @ 18	3600	2·22 -	62·	134					Connected
17·23	200 @ 38	7600	4·685 -	131·2	165					Field = Ex
17·7	200 @ 84 1000 @ 10	16,800	10·36 -	283·2	219·6					2 lamps
17·75	200 @ 84 1000 @ 20	26,800	16·52 -	443·2	156·4					4 -
17·69	200 @ 5 1000 @ 140	41,000	25·28 -	665·6	154·3					8 -
17·46	200 @ 10 1000 @ 50	48.000	29·60	774·	213·4					12 -
17·25	200 @ 10 1000 @ 250	53.000	32·68	852	209					15 -
16·87	200 @ 28 1000 @ 275	57,000	31·442	817.	154					17 -
										17 -

Temperature of the armature after 2½ hours run on full load 112° F 45°C
" on the surface of the armature 100° F 38°C
" of the air 72° F 22.5°C

Test of Fan (Ceiling Bracket) Motor 3rd August 91.

This motor is electrically similar to that whose final test is recorded on page 44a. The armature is in every respect identical, the field casting is the same with a temporary field winding of 9 layers × 30 turns to each spool = 270 turns on each spool or 5400 in all. The resistance of this was 1·50 Ω. #19 B.W.G.

The resistance of the armature was 24·75 Ω hot (100°C)

With 3 amp: in the field = 1620 amp: turns, and 7½ in the armature circuit, the speed of the motor was 1342 r.p.m. when it carried the large blades of regular pitch. The p.d. at the motor terminals was 35 volts, the pd on the mains 125. 72½ in ckt, and 1·187 amp. (90/72 = 1·25) The current increased to 1·247 when the motor was held. Assuming that the regular pressure at which the motor will run is 117 volts, the resistance needed in the field is 82/90 × 72 = 65 Ω.

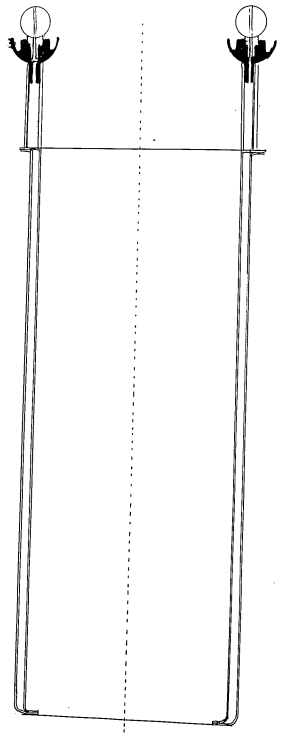
Maintaining a current of 1·3 amp: through the armature continuously raised its temperature to 208° F 98°C.

If the weight of wire allowed on each spool is 0·9 lbs = 32·5 oz @ 100°C = 40·63 Ω per lb: at 100°C. = #26 B.W.G. 41·81 = @ 100°C.

0·8 × 16 = 12·9/16 oz: of #26 B.W.G. or 1·25 lbs: of #25 B.W.G.

When wound with 1415 turns of this #25 B.W.G. wire on each spool, the motor made 1140 r.p.m. with 117 volts at terminals = 2820 turns in all. It was found that this made the field magnet too strong and the motor would not start. The right current would be 0·88 ? instead of 1·3. In addition to this the field became very warm

Full sized section of coil and case.



Test of two standard resistances of copper wire, one for the New York Works 4th August 91.

These coil are those already described on p. 21 Book III.
The cases are of nickelled sheet brass and these winding is #30 B&S double silk covered copper wire layed on in two and a half layers insulated by oiled paper. The case is soldered together watertight.
The following were the final tests of these.

Insulation O.K.

No. 1. immersed in water @ temp 22·2° C.

1000/10	3rd Lab bridge T.B. 23° C.	46·585
	Temp: corr 4° C.	0·056
		46·641
	Leads	0·069
		46·572
	Copper Temp. corr & 23·1° C	0·180
	Legal ohms @ 70° F	46·392
1000/100	with similar connections	46·727
	Mean value Ω @ 70° F	46·410

Insulation O.K.

No 2. immersed in water @ temp 22·2° C.

1000/10	3rd Lab bridge T.B. 23° C.	46·685
	Temp: corr 4° C.	0·056
		46·691
	Leads	0·069
		46·622
	Copper Temp. corr & 21·1° C	·180
	Legal ohms @ 70° F	46·442
1000/100	with similar connections	46·477
		46·460

Number 2. forwarded to the New York Works. No 1. retained.

Data concerning Chicago & South Side Rapid Transit R.R. Co.

Terminus Van Buren St. first 4 miles in almost straight line. Road as projected is 9 miles long. Speed required is 15 miles per hour including stops. The distances between stations averages 1980 feet. Some closer some further. The stand still is 17 seconds. Length of stop 400 feet with max: speed of 25 mph. Time occupied in stopping is about 20 seconds. Time between average stations 90 secs. 1980 ÷ 22 = 90 ; 90 − 17 = 73 seconds running. 73 − 20 = 53 seconds from start to break application. Based on uniform acceleration from start to max: of 25 mph. time of acceleration = 20.6 secs = 381 ft. followed by 32.4 secs of uniform run. The distance run at full speed of 25 mph. = 1199 ft.

At uniform rate of acceleration the res: of total train load is 110 lbs: per ton of 2000 lbs: for uniform acceleration and 7 lbs: for friction.

Weight of trains. Maximum will consist of 5 cars each weighing 28,000 lbs. 140,000 lbs.
Seating 50 passengers and affording standing room for 50 more or 500 passengers in all - total 500 passengers 75,000 -
Maximum weight of loaded train 215,000 -

At hours of maximum movement, trains are dispatched every one and a half minutes in both directions, although heavily loaded in but one direction.

In the case presented on the preceding page $d = 1980 - 400 = 1580$

$T = 53$, $v = 25 \times \frac{22}{15} = \frac{110}{3} = 36.\dot{6}$

$\therefore \frac{t}{2} = 53 - \frac{1580}{36.\dot{6}} = 53 - 43.1 = 9.9 \quad \therefore t = 19.8$ say 20.

$x = 36.\dot{6} \times 53 - 1580 = 1943 - 1580 = 363$

$l - x = 1580 - 363 = 1217$

$t_1 = 1217 \div 36.\dot{6} = 33.2$ say 33.

$f = \frac{m}{32} \times \frac{36.\dot{6}}{20} = \frac{275,000}{32} \times 1.8\dot{3} = 15630$ lbs. wt. total

$f_1 = \frac{215,000}{32} \times 1.8\dot{3} = 12310$ lbs. wt on drawbar.

$\frac{15630 \times 18.\dot{3}}{550} = 521$ HP. $= 389$ KW.

$\frac{700 \times 36.6}{550} = 46.6$ HP. $= 35$ KW.

424 ..

Data for the Solution of Railroad Problems.

<· · · · · · · · · · · · d · · · · · · · · · · · ·>
<· · · x (363) · · · ·> 1217

Let d be the distance from start to point of brake application
x - - - in which to accelerate uniformly.
$d-x$ - - - run over at uniform maximum speed.
T - - time occupied in passing over the distance d
t - - - - - - - - - x
v - - maximum speed.

Then $x = \frac{vt}{2}$ $\quad l - x = v(T - t)$

$\therefore \quad l = v(T - \frac{t}{2})$ or $\frac{t}{2} = T - \frac{l}{v}$

and since $(s = \frac{vt}{2})$ $\quad x = vT - l$

$f = m\frac{v}{t}$

400 ft. stop is breaking with power of 90% weight of empty car.

Allowing that the motors need be only 2/3rds. of full capacity namely $\frac{400 \times 2}{3} = \frac{800}{3} = 267$ KWts and 6 watts per lb: $= \frac{267000}{6} = 44500$ $= 22.25$ tons.

~~Wired~~ Tests of Dial Recording Clock Meter 5th 6th Aug:

The adjustment of the meter was changed at 15 oclock and the following observations made:-

No. of obs.	Time	Interval	Dial.	Record	Current		No. of obs.	Time	Interval	Dial	Record	Current
		secs.	432.5									
1	15. 30.12 / 36.25	373	445.4	12.9	10		7	15: 43.12 / 50.02	410	523.2	7.4	10
2	. 42.30 / 48.55	395	459.2	13.8	-		8	16. 55.22 / 17. 02.07	415	537.0	13.8	-
3	15 54.43 / 16.01.15	392	473.5	14.3	.		9	17. 07.30 / 12.39	.	551.8	14.8	-
4	16. 06.57 / 13.48	406	487.3	13.8	-		10	. 19.31 / 26.13	402	565.5	13.7	-
5	19.03 / 25.44	401	502.0	14.7	-		11	.		-		-
6	31.11 / 37.50	399	515.8	13.8	-		12	50.01		594.1	28.6	-

Selecting all the observations except #7 which was evidently a failure and #1 which was preliminary the total record for 10 observations was 141.3 or 14.13 for each registration.

The reading at 17.57 was 594.1, at 7.55 following morning 622.5 a change of 28.4 in 14 hours = 2.03 per hour. or 0.406 per registration.

$14.13 - 0.406 = 13.724$ is the registration for 10 amp.
1.3724 - - - - 1 amp.
$6.862\,x + 2.03$ is the constant for x amperes in 1 hour.

6th Aug: Test on 2 lamps in series Obach 0.038

8.38.00 625.0
10.14.10 630.4 96 min = 1.6 hrs. 5.4 1.6×2.03 3.248 . $5.4 - 3.248 = 2.15$
$2.15 \div 1.6 = 1.34$ per hr $= 0.2$ amp.

$\frac{0.8998}{100 \div 0} = 0.008998 \quad \frac{1}{1.224 \times 0.008998} = 818.3$

$\frac{0.008145}{100} = 0.00008145 \quad \frac{1}{1.224 \times 0.00008145} = 821.7$

Test of Dial Recording Block Meter. 6" Amp: 31. (61)

Compared reading of this meter with standard electrolytic meter as follows:—

			Measured Gains		
Weights of plates	1	44.111	89.716	#1	
	2	44.605			
	3	43.910	89.465	#2	
	4	45.555			
Time of starting	10.30.00		Dial	00.630.8	20 lamps
" " stopping	22.00.00		"	01177.2	load varied intentionally.
Weights of plates	1	44.200	+ 0.089		
	2	44.585	− 0.080	0.08945	0.009981100 69.1
	3	43.830	− 0.080		
	4	45.648	+ 0.093	0.0865	0.009401100 = 71.1

Time 11.5 hours. × 2.03 = 23.34

Record 546.4 − 23.34 = 523.06 ÷ 6.862 = 76.24 amp. hrs. Mean electrolytic 70.1

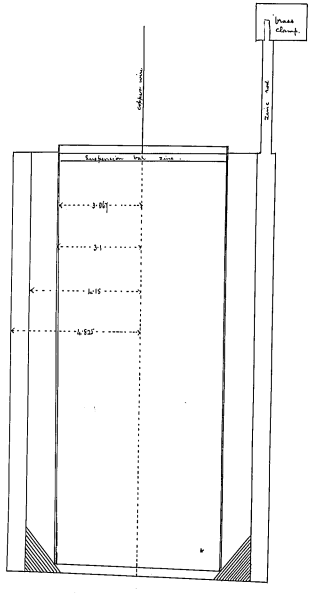
2nd test

Weights of plates	1	43.075	89.157	#1	
	2	46.082			
	3	47.570	92.292	#2.	
	4	44.822			
Time of starting	9.17.00		Dial	011953	20 lamps
" " stopping	8.45.00		"	016044.0	load varied
	21.28.00	21.5 hrs.	=	004087	

21.5 × 2.03 = 43.6445 . 408.7 − 43.6 = 365.1 ÷ 6.862 = 53.2 amp. hrs.

	1	43.199	89.219	Gain 0.0144	Loss 0.062 Mean 0.053
	2	46.020			
	3	47.520	92.470	Gain 0.128	Loss 0.030 = 0.079
	4	44.950			

Section of zinc cylinders through axis. Full size



Apparent weight of plate in solution #1 75.79 #2 78.67

scale pan	27.3	calc		27.3	calc
	103.09	+10.71		105.97	+ 10.99
Carrying rod plate #1	16.59			16.31	
plate in solution	86.5			89.66	
air	118.8			122.2	
Loss of weight in solution	15.71			16.23	

The emf at full load = 0.4 volt and for 48.4 mamp requires a res: of $\frac{0.4 \times 1000}{48.4} = 8.264$ ohms

R of bottle cct = 8.240 of which 8 ω is supposed to be in wire 5.19 of which is y.s.

Tests of 3-wire electrolytic meter 7th August 91. (62)

In amalgamating these plates the suspension bar of one inner cylinder, and the zinc rod of the outer cylinder gave way.

Revising therefore the conditions for the cell, we require 280 sq: cms: and if this be on a plate both sides of which are active = 140 sq: cms: on each side. 15 cms: in height and 10 cms: wide = 150 sq: cms: If this plate is to weigh 120 gms, and its sp. g. = 7.1 its thickness must be 0.113 cm. = 0.029"

Taking 6" x 3 7/16" = 22.5 sq in = 145.2 sq: cms: x 2 = 290.4 total surface 0.01" = 0.10 cms say 0.11 cms. = 15.97 c. c. say 16. = 103.8 gms. At the rate of 5.84 mgms: per amp: hr: of actual loss, or 103.8 x 6/7.11 = 87.6 gms: of apparent weight and 5 mgs per amp: hr of apparent loss, 1/20th. of the plate or 58.4 gms: would last 11,670 hours. This is for a 20 lt meter whose full load would be 10 amperes. Direct lights sell on the average for three hours each daily, 300 ampere hours would be the average record for one day and 38g days would consume the whole 58.4 gms (apparent).

The volume of Zn 20% displaced is 16 c.c. @ 1.11 = 17.76 gms: The error produced per °C is 0.00075 x 17760 = 1776 x 0.75 x 10 = 13.32 mgms representing 2.66 amp: hr. The total range of temperature is from 41.5° C to 32.2° C = 27.7° x 2.66 = 73.7 amp: hr. This would be the total error if it all occurred at any one time.

1 milliampere will transfer 1.2244 mgms per hour
or apparently $1.2244 \times \frac{6}{7.11} = 1.033$ mgms ..
∴ 48.84 milliamps will transfer 5 mgms apparently per amp: hr

The surface of active zinc in the present meter bottle is 17.7 sq cms, and it carries 0.817 mamp: the current density is thus 0.046 mamp: per sq cm.

The surface in this meter will be 290.4 and the current 48.84 mamp corresponding to a density of 0.0173 mamp: per sq.cm. = 2.66 times that in the present standard.

As actually completed, the plates have a length of about 5.75", a breadth of 3.75" and a weight in air of 105 gms: approx. Their sp. g. before amalgamation is 7.15. They taper in thickness downwards. Two wires 0.010" are soldered to the upper edge, and hold the plates up. The clearance has a mean value of 1 cm. so that there are 280 sq cms: of surface active with a height through liquid (1.110) of 1 cm. About ½" of paraffin - (Russian*) oil is poured on the surface and the edges of the glass cells painted with paraffine wax.

Where set up at noon 17th Sept. Plate #1 weighed 75.79 gms res: 0.16Ω
Apparent weight in solution " #2 " 78.67 " 0.16Ω

The weight of the stationary zincs in cell #1 371 gms
" carrying + suspender " " #2 118.8 in air
" of the stationary " " 375.5
" carrying + suspender " " 122.2
" carrying + basin pan 27.30

actual weights of the plates in solution are thus #1 103.09. in 1.11
#2 105.97.

weight of carrying on #1 plate in air 16.59.
#2 " " " 16.31.

* exchanged later for paraffine oil.

Test of Storage Battery Plates received from Canada.

These plates were received without jars from the Canadian District Office. They were 20 in number, half positives and half negatives. Each plate measures 10 × 10 × 1.3 and is perforated by a number of holes containing special material. The weight of each plate is about 620 gms.

They were made up into four cells each with five plates and exposing therefore 4000 sq. cms. each of active surface separated by about 0.6. The plate were set horizontally one above the other. The plates are positive. The plates differed in color and were partly charged when received. The cells were filled up with dilute H_2SO_4 and discharged. The density of solution was adjusted to 1.15. By means of an Edison meter in circuit the total amount of charge was found to be 52.5 amp. hrs. in each cell. The amount of discharge realized subsequently after 24 hours intermission was 52.5 amp. hrs, or 84% of the charge. The weight of the plates is 2 lbs. each wet or 10 lbs. per cell representing

5.25 amp-hrs. per lb. of weight of wet plate
8.8 - - - - - - dried -
3.5 - - - - - - cell weight, allowing 3 lbs. of cell to the plate
11.57 amp. hrs per kgm. of wet plate
19.11 - - - - - dry.
7.72 - - - - - cell weight

A copy of a certificate from the Central Electrical Laboratory (Paris?) gives the following particulars for one cell.

Weight of plates 2.14 Kgs. Weight of cell complete 6.8 Kgs.
First charge not measured.
First discharge drawn to EMF of 1.85 at 1 amp. per kg. or 2.5 amp = 77 amp. hrs. or 32 amp-hrs per kg. of plates weight.
Second charge 0.8 amp. per kg. = 2 amp 81.5 amp. hrs.
- discharge 1 - - - = 2.8 - 67.5 - - = 33.3 amp-hrs per kg.

Ceiling fan motor tests on completion and before shipment 8th August 91.

(64)

For further particulars of this motor see p. 56.
The armature is identical in dimensions and winding with the 120-volt armature in the upright model, whose final test appears on page 60a. F

The field winding consists of 350 turns of #26 B.W.G. wire on each spool
Total 700 turns 11.0 ω @ 27°C. = 10.7 ω @ 20°C. = 0.348 lb. = 5½ oz.
In circuit with the field and armature is a resistance of 38.4 ω
#26 B.W.G. 142.5 lbs (1 lb. 2oz) wound in 400 turns on a ring 95/16" in diam. = 37.4 ω @ 20°C.

The total resistance of field armature and spool at 27°C = 71.9 ω (apparent with little error) 1.63 ?
20°C = 70 ω 1.67
60°C = 90 ω 1.96
80°C = 96.2 ω 1.36

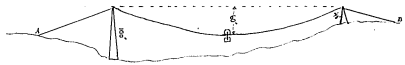
After passing the current for about ten minutes through the machine with the armature arrested, the temperature on the surface of the spool rose to 70°C. from 27°C., and the resistance of the machine increased to 89 ω representing a mean temp. of about 85°C. The pot was 125 volts. This is about the most severe test that could be applied. The speed of rotation with the large fans in position varies from 50 to 500 rpm. according to their angle with the vertical plane. The fan was operated for several hours without any undue warmth.

Comparative test of five transformers for fall of pressure 8th Aug.

Transform	A load	B load	volts on A	Pri. res.	Sec. res.	Pabble drop	Exter. drop	% of exter. drop	Pri. current act.	Pri. drop act.	equivalt sec. drop	Sec. current	Sec. drop	Total	Drop
T. H. 15 light	0	0	117.4	33 ω	0.3 ω										
	1.6	1.6	117.0						0.3	10.0	1.25	1.6	12.5	1.75	0.12
	3.2	3.2	116.6												0.8
	4.8	4.8	116.3												1.1
	6.4	6.4	115.9												1.5
	8.0	8.0	115.5												1.9
	9.6	9.6	115.2						1.3	43	5.4	9.6	2.9	8.3	2.2
½ Watt	0	-	116.9	12 ω	0.02										
	3.2	-	116.8												0
	6.4	-	116.8												0.1
	9.6	-	116.4												0.4
	12.8	-	116.1												0.7
	16.0	-	116.0												0.8
	19.2	-	115.8												1.0
	22.4	-	115.5												1.3
	25.6	-	115.0												1.7
	28.8	-	114.75												1.95
	32.0	-	114.6						2.1	25.2	1.6	6.4	2.24		2.3

On the 12th inst. a test was made with the large ① transformer with the secondary wire beneath, and the primary winding overlying it above. The drop between 0 lamps and 20 lamps on each side — (full load of forty lamps being 5 volts 123 and with A 0 and B 0 and 118 volts on A with A 20 and B 20. Instead of 15 volts drop under the same conditions of assembling but with the coils side by side.

Transf. mark	A load	B load	volts on A	Drop	Pri. res.	Sec. res.	Pabble drop	Exter. drop	% of exter. drop	Pri. current	Pri. drop	Equivalt Sec. drop	Sec. drop	Total
£.	0	0	123	0	9 ω	0.5 ω	-	-	-	0.9	8.0	0.8	0	-
	4.8	4.8												
	9.6	9.6	121.5	1.5			1.075	1.425		1.25	5.0	1.25	0.9	2.15
	2.7	2.7	120.5	2.5			1.5	1.0	0.5	0.75	6.3	1.7	1.3	3.0
	5.4	5.4	119.5	3.5			2.0	1.5		1.0	9.0	2.25	1.8	4.0
	8.1	8.1	118.75	4.25			2.5	1.75		1.25	11.3	2.8	2.5	5.0
	5.4	5.4	117.75	5.25			3.0	2.25	1.5	1.5	13.5	3.4	3.0	6.0
	6.3	4.3	118.8	6.2			3.5	2.7		1.75	15.8	3.9	3.5	7.0
	7.2	4.2	117.6	5.4			4.0	3.4		2.0	18.0	4.5	4.0	8.0
	8.1	8.1	116.5	6.5			4.5	4.0		2.25	20.3	5.1	4.5	9.0
	9.0	9.0	113.5	9.5			5.0	4.5		2.5	22.5	5.6	5.0	10.0
										2.8	25.2	6.4	5.7	11.4
Type ①	0	0	121.5	0	6.86	0.25				0.9	8.0	0.8	0	-
	0.9	0.9	121	0.5										
	1.8	1.8	119.5	2.0			0.65	1.35		0.25	2.25	0.56	0.45	1.01
	3.7	3.7	118.3	3.2			0.9	2.1		0.35	3.15	0.8	0.65	1.45
	3.6	1.6	117.3	4.2			1.1	3.0		0.5	4.5	1.1	0.9	2.0
	4.5	4.5	115.5	6.0			1.4	4.6		0.6	5.4	1.4	1.2	2.6
	5.4	5.4	114	7.5			1.75	5.75		0.75	6.75	1.7	1.5	3.2
	6.3	6.3	113	9.0			2.1	7.4		0.85	7.65	1.9	1.7	3.6
	7.2	7.2	110.2	11.3			2.35	9.0		1.0	9.0	2.25	2.0	4.25
	8.1	8.1	108.5	13.0			2.65	10.4		1.1	9.9	2.5	2.2	4.7
	9.0	9.0	106.5	15.0			3.0	12.0		1.25	11.25	2.8	2.5	5.3
							3.4	13.6		1.4	12.6	3.2	2.8	6.0
							3.8	15.2		1.5	13.5	3.4	3.0	6.4
							4.2	16.8		1.6	14.4	3.6	3.2	6.8
							4.6	18.4		1.75	15.75	3.9	3.5	7.4
							5.0	20.0		1.9	17.1	4.3	3.8	8.1
							5.4	21.6		2.0	18.0	4.5	4.0	8.5
							5.8	23.2		2.1	18.9	4.7	4.2	8.9
							6.2	24.8		2.2	19.8	5.0	4.4	9.4
							6.6	26.4		2.3	20.7	5.2	4.6	9.8
							7.0	28.0		2.4	21.6	5.4	4.8	10.2



For hard copper $\bar{\rho}$ @ 20°C = 1.75×10^{-6} ω.
$\bar{\sigma}$ = 8.95
$\bar{p}$ = $\frac{0.29}{2.234}$ = 4.409×10^{-2}
$\bar{\rho}\bar{\sigma}\bar{p} = 6.965 \times 10^{-7} = 3.453814$

- soft wire ρ @ 20°C = 13.16×10^{-6}
σ = 7.85
p $\frac{0.43}{2.234}$ = $.6412 \times 10^{-5}$
$\rho\sigma p = 6.836 \times 10^{-9} = 2.277 \times 10^{-7} \times f$

To find the distribution of stresses in a portage system for carrying ore. (65

Distance A B 1700 feet. Assumed distance between towers 1200'
Weight of rope 7 lbs. per foot. Weight of ore skip 8000 lbs. Say at centre 60'.

If 6' of rope make the unit, the stress at each tower becomes
$510 \times 6 = 3060' \times 21420$ lbs: due to rope alone.
4 tons will produce at the centre 50 tons on the two ends or 50,000 lbs; on each end, making the pull on catenary 71,420. lbs.

Tests of 1 KW Transformer E. type continued from p. 53.
14th Aug. 91.

The primary was rewound with 700 turns of #19 B.W.G. 0.0422" dia. & 0.05 resistance 0 cool 0 58°C and 0.582 hot @ 58°C.

The drop for 4.5 amp. with these windings is 2.4 volts.
The drop actually observed is 7.3 volts with 20 lamps on each side (A.0 B 0 A = 118.8 A 20λ. B 20λ. A = 111.5) and 3.5 volts with 10 lamps on each side (A.0, B 0, A = 117.5. A 10λ, B 10λ, 114.0)

The secondary as before consists of 172 turns of #14 B.W.G. 0.080"dia & 0.099". Resistance @ and @ 58°C. 0.5800.

The transformer was operated at full load, held in wooden clamps, and resting on a table from 9 till 23 o'clock, with one hours intermission at noon. The highest temperature reached was 160°F (70°C) the air being 27°C (80°F), an elevation of 43°C.

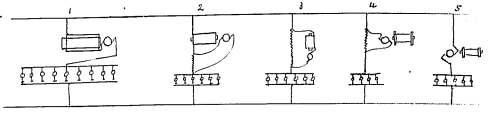
On the following morning (15th Aug.) it was operated on no load from 8. till 13 o'cl. The temp reached was 129°F (54°C) the air being 80°F (27°C) a rise of 49°F (27°C)

On the relative costs of different metals as commercial conductors

Let $\bar{\rho}$ be the resistivity of the standard metal at working temp.
ρ - - - - - - metal to be compared.
$\bar{\sigma}$ - - specific gravity - - standard metal
σ - - - - - - metal to be compared
$\bar{p}$ - - price per gramme of the standard metal
p - - - - - - - metal to be compared
P - - - of a length l cms of wire to offer a given re

A wire 1 cm: long and 1 sq: cm: area of standard, will weigh $\bar{\sigma}$ gms. costing $\bar{\sigma}\bar{p}$ and offer $\bar{\rho}$ ω.
- - 1 - - - - new metal - - σ - - σp & - - ρ ω

The area of the new wire must to have ρ ohms be altered in the ratio $\frac{\rho}{\bar{\rho}}$
This will increase the weight per cm: from σ to $\frac{\rho\sigma}{\bar{\rho}}$ and the cost will be $\frac{\rho\sigma}{\bar{\rho}} p$ per cm: The ratio of cost per cm will be $\frac{\rho\sigma p}{\bar{\rho}}/\bar{\sigma}\bar{p}$
or $\frac{\rho\sigma p}{\bar{\rho}\bar{\sigma}\bar{p}}$



Consider the case of a motor whose armature has a secondary winding of n_2 virtual turns of r_2 virtual resistance short-circuited upon itself. We may suppose that the energy expended in driving this coil during the rotation of the armature is so large compared with mechanical friction and hysteresis that the torque due to these latter may be ignored.

Then $e_2 = \varphi n \omega_2$

$c_2 = \frac{\varphi n \omega_2}{r_2}$

$\tau = \frac{\varphi c_2 \omega_2}{2\pi} = \frac{\varphi^2 n \omega_2^2}{2\pi r_2}$

by (3) $\therefore \quad n = \frac{E}{\varphi\omega} - \frac{2\pi R}{\varphi^2\omega^2} \cdot \frac{\varphi^2 n \omega_2^2}{2\pi r_2}$

$= \frac{E}{\varphi\omega} - n\frac{R}{r_2} \cdot \frac{\omega_2^2}{\omega^2}$ Let $\omega_2 = \alpha\omega$ and $R = \beta r_2$

$= \frac{E}{\varphi\omega} - n\alpha^2\beta$

$\therefore n(1+\alpha^2\beta) = \frac{E}{\varphi\omega}$

or $n = \frac{E}{(1+\alpha^2\beta)\varphi\omega}$ or $\propto E$

If $\omega_2 = \omega_1$ and $r_2 = R \quad \alpha = 1 \quad \beta = 1$

$n = \frac{E}{2\varphi\omega}$

On the equations of motion of a motor. 66

Let E be the emf impressed on a circuit containing a motor in opposition to the impressed emf produced by the motor due to all causes.

r - - res: of the motor

r_2 - - - rest of the circuit

R - - total res: of the circuit $(r + r_2)$

c - - current in the circuit

φ - - polar flux

n - - no: of revs: per sec:

ω - - - wires all round

e - - counter-emf. of the motor.

Then $E = e + cR$ and $ec = 2\pi n \tau$ (1)

$= \varphi n \omega + \frac{2\pi R \tau}{\varphi\omega}$ (2)

$\therefore n = \frac{E}{\varphi\omega} - \frac{2\pi R \tau}{\varphi^2\omega^2}$ This is the fundamental speed equation (3)

In case 1, E, ω, ρ are constant $R + \tau, \varphi$ and n are variable

Let $\rho = 0$ and $\varphi = \Phi$ a constant Let $r_2 = R$

$\frac{n}{\tau} = \frac{E}{\varphi\omega R} - \frac{2\pi}{\varphi^2\omega^2}$ $ec = 2\pi n \tau$

$\frac{dn}{d\tau} = -\left(\frac{2\pi R}{\varphi^2\omega^2}\frac{d\tau}{d\varphi} = \frac{2\pi\tau R^2}{\varphi^2\omega^2}\right)$ = a constant λ say $\quad \varphi n^2\omega^2\alpha = 2\pi n\tau$

$\therefore -\lambda\varphi^2\omega^2 = 2\pi\left(R\frac{d\tau}{d\varphi} = 2\pi\tau R^2\right)$ $\quad \therefore \tau = \frac{n\varphi\omega\alpha}{2\pi}$

If $\tau = \beta R^2$

$\therefore \lambda\varphi^2\omega^2 = 2\pi(2\beta = \beta) = 2\pi\beta \quad \therefore \varphi = -\frac{\lambda\varphi^2\omega^2}{2\pi}$

In this case it is necessary that φ should be constant, roughly, and $\tau \propto R^2$

In case 2, φ, ω, ρ are constant E variable $\tau = 0$

$\frac{dn}{dE} = \frac{1}{\varphi\omega} - \frac{2\pi R}{\varphi^2\omega^2}\frac{d\tau}{dE}$ = a constant μ say

$\therefore \mu = 1 - \frac{2\pi R}{\varphi\omega}\frac{d\tau}{dE}$ if $\tau = \alpha n$

$\mu = 1 - \frac{2\pi\alpha R}{\varphi\omega}\mu$

$\mu\left(1 + \frac{2\pi\alpha R}{\varphi\omega}\right) = 1$, an equation satisfied if $\mu = \frac{\varphi\omega}{\varphi\omega + 2\pi\alpha R}$

In this case it is necessary that $\tau \propto n$ or the retarding force shall vary as the speed, $\varphi\ \omega\ R$ being constant.

Case 3 coincides with case 2 if φ be assumed constant.

In 3 this must be produced by a large amount of copper on the field winding. In 4 by a permanent magnet.

Case 5 coincides with case 1 if φ be assumed constant.

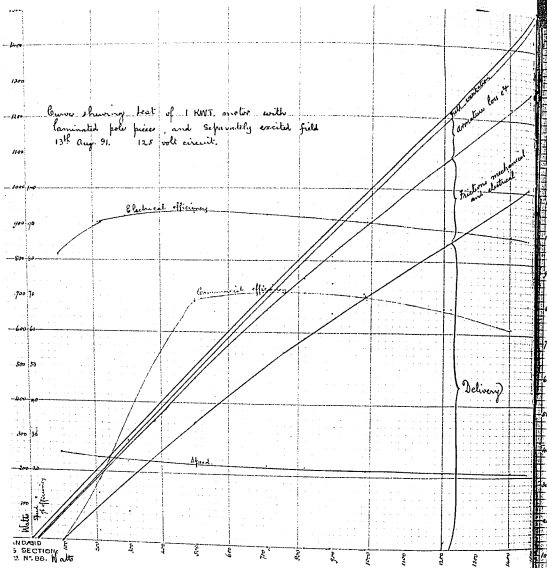
It is important to observe that cases 2 3 + 4 will be satisfied provided τ is independent of the speed and constant, but in this case the term $\frac{2\pi R\tau}{\varphi^2\omega^2}$ must be small compared with n.

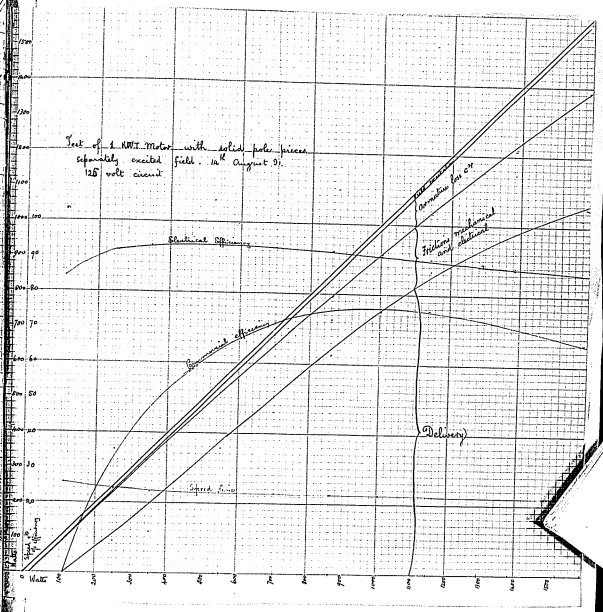
Pole pieces laminated

Mark obs	P.D. at index amm	Ohmic	Amp.	Activity in amm	Current in field	R. of field	Activity in field	Res. of amm	Drop in amm	Activity lost in amm	Effort	E.M.F. of amm	Speed of amm
1	12.1	0.125	0.645	78.	3.82	1.15	16.78	1.0	0.6	0.36	77.6	120.4	1520
2	122.5	0.305	1.574	193.					1.6	2.56	190.4	120.9	1240
3	122.	0.446	2.302	281					2.3	4.69	276.3	119.7	1400
4	120.	0.785	4.052	486.					4.1	16.8	469.2	115.9	1200
5	119.	1.130	5.831	694.					5.8	33.6	660.4	113.2	1375
6	117.5	1.320	6.812	800.4					6.8	46.2	754.2	110.7	1350
7	116.0	1.480	7.638	870.6					7.6	57.8	812.8	106.4	1330
8	115.0	1.640	8.462	973.2					8.5	72.3	900.9	106.5	1310
9	113.0	2.025	10.450	1181.0					10.5	110.3	1070.7	102.5	1300
10	112.0	2.40	12.395	1387.					12.4	153.8	1233.2	99.6	1240
11	107.5	2.62	13.52	1454.					13.5	182.3	1271.7	96.0	1225

S. E. F.

Mark obs	P.D. at index amm	Ohmic	Amp.	Activity in amm	Current in field	R. of field	Activity in field	Res. of amm	Drop in amm	Activity lost in amm	Effort	E.M.F. of amm	Speed of amm
					3.72								
1	12.5	0.143	0.735	92.3	3.12	1.15	16.79	1.0	0.7	0.5	91.8	124.3	1550
2	123	0.370	1.909	234.8					1.9	3.6	231.2	121.1	1440
3	121.5	0.538	2.776	337.3					2.8	7.8	329.5	118.7	1405
4	119.0	0.874	4.510	536.8					4.5	20.3	516.5	114.5	1390
5	119.0	1.120	5.780	687.8					5.8	33.6	654.2	113.2	1360
6	118.0	1.340	7.173	846.5					7.2	51.8	794.7	110.8	1350
7	116.5	1.640	8.463	985.8					8.5	72.3	913.5	108.	1330
8	115.0	1.900	9.804	1128.					9.8	96.0	1032.	105.2	1315
9	113.8	2.175	11.23	1278.					11.2	125.4	1153.6	102.6	1300
10	110.5	2.400	12.38	1368					12.4	153.5	1214.2	98.1	1225
11	110.	2.65	13.67	1504.					13.7	187.7	1316.3	96.3	1200
12	113.	2.75	14.19	1604.					14.2	201.6	1402.4	98.8	1315
13	113.25	2.70	13.93	1577					13.9	193.2	1383.8	99.4	1320


Curves showing heat of 1 KWT. motor with laminated pole pieces and separately excited field 13th Aug. 91. 125 volt circuit.
Total Input
Armature loss C²R
Friction mechanical and stray
Electrical Efficiency
Commercial Efficiency
Delivery
Speed
Watts
Electrical Efficiency
INDEXED
S SECTION
S No. 86. WATTS


Test of 1 KWT Motor with solid pole pieces separately excited field. 14th August 91.
125 volt circuit
Total Input
Armature loss C²R
Friction mechanical and stray
Electrical Efficiency
Commercial efficiency
Delivery
Speed Curve
Watts
Electrical Efficiency

Tests of 1 KWT. Motor wound for 120 volts.

13th Aug.

Armature connected to commutator by short lengths (7 cms) of #23 B&S wire. Field separately excited. Commutator 72 blocks but only 36 armature sections

Amps.	EMF per arm.	Balance	Moment	6165 × Moment	Activity delivered watts	Activity in watts	Commu. eff.	Elect. eff.	Load	Volts at dyn. brushes	Time	Friction watts
0	4·753	0			0	95	0	0·817	Light		15·40	786
5	5·037	200 @ 10	2000	1·233 x10⁷	29·6	210	0·141	0·907	Burnt 1HP motor		·45	168·8
5	5·132	200 @ 30	6000	3·699	86·3	298	0·29	0·927	S.E.F	130?	·50	190·0
10	4·967	200 @ 30 / 1000 @ 2.0	24,000	14·79	344·5	503	0·686	0·933	2 λ	"	16·00	127·2
15	4·943	2000 @ 2.0 / 1000 @ 2.0	36,000	22·19	508	711	0·714	0·928	4 λ	"	·05	152·4
20	4·920	200 @ 10 / 1000 @ 40	42,000	25·89	582·7	817·	0·712	0·923	6 λ	"	·08	161·5
25	4·80	1000 @ 20 / 200 @ 10	45,000	27·57	656·2	887	0·739	0·916	8 λ	"	·15	156·6
30	4·883	1000 @ 20 / 200 @ 88	51,600	31·81	693·4	990·	0·700	0·910	10 λ	"	·30	207·5
35	4·745	1000 @ 60	60,000	36·99	801·5	1198	0·669	0·894	12 λ	"		269·2
40	4·633	1000 @ 60 / 200 @ 2.5	65,000	40·07	861·4	1401·	0·613·	0·878	14 λ	"		272·8
45	4·609	1000 @ 60 / 200 @ 40	80,000	49·32	1006·	1471	0·684	0·864	16 λ	120	17·15	265·7

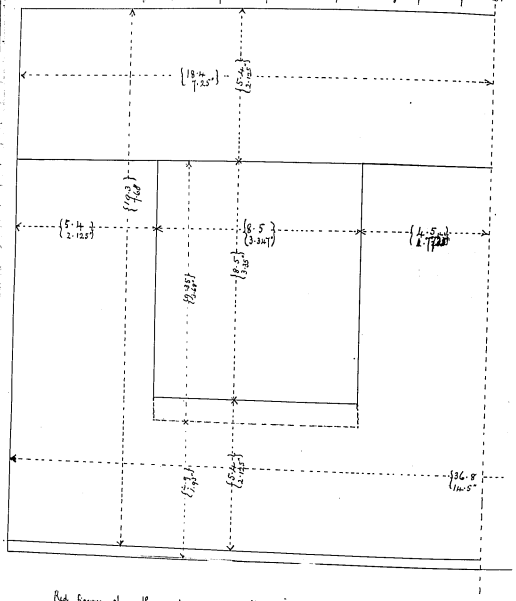
Test repeated on following day with solid pole pieces

Amps.	EMF. per arm.	Balance	Moment	6165 × Moment	Activity delivered	Activity in watts	Commu. eff.	Elect. eff.	Load	Volts at dyn. brushes	Time	Friction
0	4·847	0	0		0	109	0	0·842	Light		12·0	91·8
5	5·026	200 @ 30	6000	3·699	86·98	252	0·352	0·918	Burnt 1HP motor			142·4
10	5·072	200 @ 40	8000	4·932	115·4	356	0·326	0·931	S.E.F			214·1
15·17	4·941	1000 @ 25	25,000	15·405	356·9	554	0·644	0·932	2 λ			189·6
20·6	4·995	200 @ 5 / 1000 @ 35	36,000	22·19	582·9	705	0·713	0·928	4 λ			151·3
25·5	4·922	1000 @ 45	45,000	27·74	624·2	864	0·723	0·920	6 λ			172·5
30·17	4·872	1000 @ 55	55,000	33·91	751·6	1003·	0·750	0·910	8 λ			261·9
35·9	4·804	1000 @ 60 / 200 @ 20	64,000	39·45	864·2	1145	0·755	0·901	10 λ			267·8
40·7	4·728	1000 @ 60 / 200 @ 30	66,000	40·69	883·2	1293	0·686	0·891	12 λ			270·4
50·4	4·810	1000 @ 60 / 200 @ 70	78,000	48·15	880·4	1385	0·636	0·877	14 λ			323·8
60·0	4·815	1000 @ 60 / 1000 @ 40	82,500	50·86	1017·2	1521	0·668	0·865	16 λ			399·1
61·9	4·511	1000 @ 60 / 200 @ 40·5	82,500	50·86	1114·0	1621	0·687	0·876	16 λ			288·4
62·0	4·518	1000 @ 60 / 200 @ 55	77,500	47·78	1051·0	1594	0·659	0·868	16 λ		17·45	332·8

Temp: on arm: after 4 3/4 hours of run (4 hrs at full load) = 50°C. Air 27°C.
Res: of armature warm 1·08 ω field warm 1·15 ω

Breadth (finished) 9.0 cms. (3.55")

Full size Section of transformer half. Through plane of sheets.



Red figures show the subsequent modifications in groove dimensions.

Design for a (a) 2 K.W.T. Transformer (140 lamps) of the E type 17th August 1891.

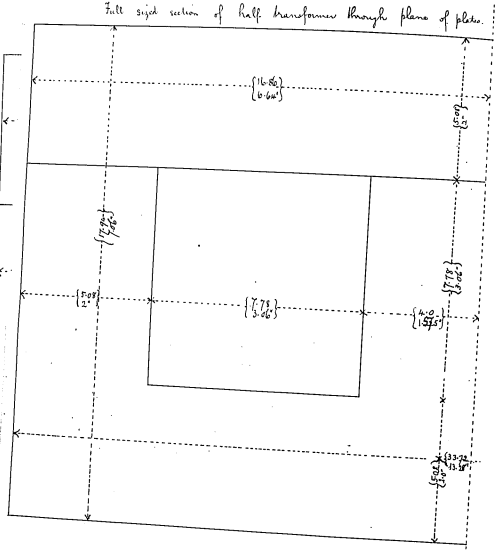
(68)

Primary effective voltage	1000	
Secondary " "	120	at no load 116 at full load.
Primary " current	2·5	" full "
Secondary " "	9·0	" " "
Primary winding	700	turns of # 15 B.W.G. 0·072" d.c.c. to 0·084"
Secondary "	172	" # 13 B.W.G. (double) 0·095" d.c.c. to 0·108" brought out at the 86th double turn for 3-wire method
Length of mean turn 4(17·5)	=	70 cms. = 2·3'
" " primary winding	=	49000 cms = 1610'
" " secondary "	=	11,040 " = 395·6' each.
Weight " primary "	=	25·3 lbs.
" " secondary "	=	10·82 lbs × 2 = 21·6 lbs.
Total Weight of copper "	=	46·9 lbs.
Res. of primary "	=	3·21Ω @ 20° C. 3·67Ω @ 60° C 4·13Ω @ 100° C
" " secondary "	=	0·266Ω " 0·259Ω " 0·292Ω "
Drop in primary at load	=	9·2 volts @ 60° C. = 2·3 equivalent
" " secondary " "	=	2·3 " " "
Total secondary drop	=	4·64 volts = 2·3 nom each side.
Mean Length of Mag: ckt.	=	50 cms.
Gross section of central core	=	9×9 = 81 sq: cms × 0·93 = 75·3 effective.
" " rest of core	=	10·8×9 = 97·2 sq: cms × 0·93 = 90·4 "
Assumed value of Φ	=	~~40,000~~ 226,800
Maximum " " B	=	~~2,430~~ 3,010
Area of air gaps	=	4·5×2×9 = 81 sq: cms. and 5·4×2×9 = 97·2 sq: cms
Winding space section	=	8·5×8·5 = 72·26 sq: cms. $(3.347")^2$ = 11·20 sq: ins
L/A of magnetic ckt	=	$\frac{8·5}{81} + \frac{41·5}{99·4} = 0·105 + 0·459 = 0·564$.
Space occupied by primary	=	700 × 0·084 × 0·084 = 4·94 sq: ins.
" " secondary	=	344 × 0·108 × 0·108 = 4·01 sq: ins
Total space for winding	=	8·95 sq: ins.
Coefficient for practice & insulation	=	1·25.
Surface of iron on one side	=	2(18·4 × 19·3 − 72·26) = 2(355·1 − 72·3) = 565·6 sq: ins
" " " top	=	2(19·4 × 9·0) = 331·3
" " " side	=	2(19·3 × 9·0) = 173·7 Total 2060 sq: cms.
Volume of iron	=	525·6 × 9 × 0·93 = 44·00 c.c.
Sp. g.	=	7·8
Mass	=	34·32 kgms = 75·66 lbs.
Weight of transformer proper:- (primary & secondary) core	=	46·9 lbs. @ $0·20 = $9·38 or 0·238 per lamp.
	=	75·66 0·05 = ~~$3·78~~ $3·78 0·0957 "
		122·56 = ~~$13·16~~ $13·16 0·333 "

Primary ckt waste in conduits	=	$2·5^2 \times 4$ = 25 Watts
Secondary " " "	=	$9^2 \times 0·19$ = 24 "
		Total 49 "

Breadth finished 8 cms.

Full sized section of half transformer through plane of plates.



RESULTS AND DATA OF TESTS ON 2 EFFICIENT TRANSFORMERS.

[illegible] 6 lbs.

Design for a (b) 2 KWT. Transformer of less marginal security. Auxiliary to that on last page. El type 17th Aug. 91.

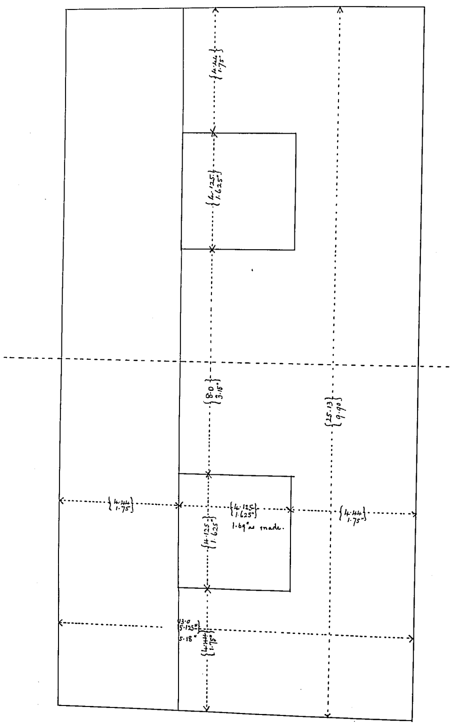
Primary effective voltage = 1000 volts
Secondary - - = 120 - at no load.
Primary - current = 2.5 amperes at full load.
Secondary - - = 9.0 - - - -
Primary winding = 700 turns of # 14 B.W.G. 0.064" d.c.c. & 0.076"
Secondary - = 172 - - # 11 B.W.G. 0.120" - - - 0.132"
brought out at the 86th double turn for neutral.
Length of mean turn 4(15.78) = 63.1 cms = 2.07
" " primary winding = 1480'
" " secondary " = 395'
Weight - primary - = 18.1 lbs.
- - secondary - = 15.5 -
Total weight of copper = 33.6 -
Resistance of primary = 3.64Ω @ 20°C., 4.17 @ 60°C., 4.70 @ 100°C.
- - secondary = 0.255 Ω - 0.292 - 0.329 -
Drop in primary at load = 10.4 volts @ 60°C. equivalent to 2.7
- - secondary - = 2.6 - - - - 2.6
Total secondary drop - - = 5.3 - - = 2.65 on each side.
Mean length of magnetic ckt = 47 cms.
Cross section of central core = 8×8 = 64 × 0.93 = 59.5 effective.
- - - rest of - = 25.08×8 = 81.28 × 0.93 = 75.6 -
Assumed value of Φ = 266,800
Maximum - - B = 2690 3000
Area of air gaps = 64 sq cms central and 81.3 on sides.
Winding space section = (7.78)² = 60.53 sq cms. = 9.364 sq ins.
L/A of magnetic ckt. = 80/59.5 + 39/75.6 = 0.134+5 + 0.515 = 0.65
Space occupied by primary = 700 × 0.076 × 0.076 = 4.04 sq ins.
- - secondary = 172 × 0.134 × 0.134 = 3.09 - -
Total space = 7.13 sq ins.
Coefficient for practice, and insulation = 1.31
Surface of iron on one side = 2 × 16.06 × 17.94 − 2(7.78)² = 605 − 121 = 484
- - - top = 33.7 × 8 = 269.6
- - - side = 17.94 × 8 = 143.5
Total surface of iron = 1994 sq cms.
Volume of iron = 484 × 8 × 0.93 = 3600 c.c.
Mass @ 7.8 = 28,100 grs. = 61.93 lbs.

Weight of transformer proper Wire = 33.6 lbs. @ 0.20 = $ 6.72 @ $ 0.168 per lb.
- - - Iron = 61.9 - @ 0.05 = $ 3.095 @ $ 0.075 - -
95.5 - = $ 9.815 $ 0.243 -

Primary c.t. waste (2.5)² × 4.29 = 26.3 watts
Secondary - - (9.0)² × 0.3 = 27.3 -
Total 53.6 -

Full sized section of transformer through plane of plates.

Breadth 8 cms (3.15")



Prima[illegible]
Second[illegible]

PARTICULARS AND DATA OF EDISON MODEL 500 WATT TRANSFORMER

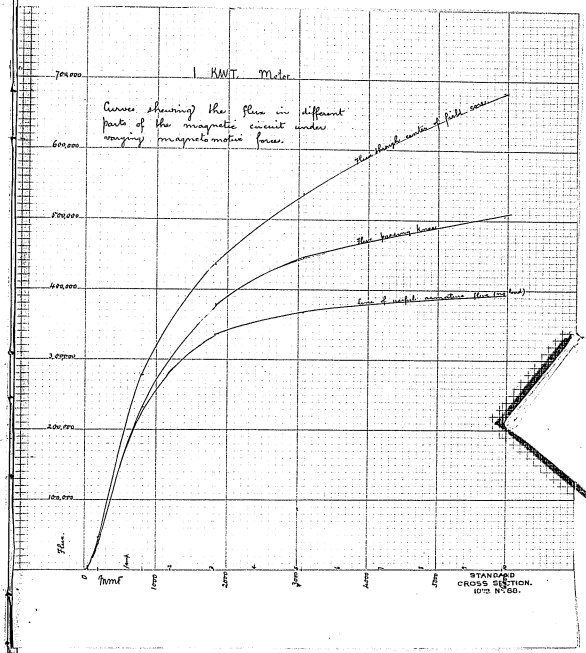
Primary effective voltage 1000
Secondary " " 120
Primary current at full load 0.[illegible] amp.
Secondary [illegible] 2.25 "
Primary winding 200 turns of [illegible] 0.028" dec. to 0.040"
Secondary 172 " " [illegible] 0.052 dec. to 0.070"
Secondary winding brought out at the [illegible] turn for neutral connection.
Weight of primary coil 2.[illegible] lbs.
secondary coil [illegible] lbs.
Total weight of copper wire 5.5 lbs.
Resistance of primary coil [illegible] ohms at 20 C. [illegible] ohms at [illegible]
secondary coil 0.[illegible] 1.0[illegible]
Drop in primary at full load (100C) = 1.40 volt in secondary
Drop in secondary at full load and (100C) 1.2 volts.
Total secondary drop at full load 100.C. 2.[illegible] volts.
Extra drop due to leakage 0.
Total weight of iron in box, lid, and side pieces with rivets [illegible] 1/2 lbs.
Iron plates 0.00[illegible]" Breadth over plates 3.0"
[illegible]nished Dimensions of plates:- Boxes
Length [illegible]"
Breadth 3.1[illegible]"
Depth of groove 1.6[illegible]"
Breadth of groove 1.625"
Core breadth 1.15"
Breadth of side wall 1.75"
Depth of base 1.[illegible]"
Lids:- Length [illegible]"
Breadth 1.75"
Rivet holes 15/[illegible]ths.
Six rivet holes in box, three in lid.
Sleeves of fiber as insulators over rivets.
Diameter of rivets 3/16ths. 0.1875"
Thickness of fiber for sleeve 0.010"
Thickness of side plates 1/8".
Surfaces in contact of box and lid planed true.
Weight of clamps [illegible] lbs. (pair).
Total weight of transformer without shell 45 lbs.
Weight of cast iron shell [illegible] lbs.
Total weight of transformer complete [illegible] lbs.
Insulation round core fiber 0.010" between coils and between coils and frame mica and rubber tape.
Temperature elevation of outside shell after 24 hours full load 45 F. (25 C.)
Temperature elevation of iron core after 24 hours load 110 F. or [illegible]1 C.
Temperature elevation of copper wire by resistance test after 24 hours full load 1[illegible] or [illegible]0 C.
Loss of power in transformer at no load 76 watts.
full 98
Commercial efficiency at full load [illegible]

Design for a 500 Watt Transformer (10 lamps)

Primary effective voltage	=	1000
Secondary " "	=	120 volts at no load.
Primary . current	=	0·63 amp.
Secondary . "	=	2·25 .
Primary winding	=	700 turns of # 22 B.W.G. 0·028" d.c.c. & 0.040".
Secondary "	=	172 . . 17 . 0.058" . . 0.070".
		taught out at the 86th turn for neutral.
Length of mean turn	=	4 × 12.12 = 48·5 cms = 1·59'.
" . primary winding	=	33950 cms. = 1113'
" . secondary "	=	8344 " = 273·5'
Weight . primary coil	=	2·648 lbs.
" . secondary "	=	2·79 "
Total " coils	=	5·44 "
Resistance . primary coil	=	14·66Ω @ 20°C. 16·76Ω @ 60°C. 18·8Ω @ 100°C.
" . secondary "	=	0·84Ω " 0·96Ω " 1·08Ω "
Drop in primary at load	=	10·56 volts @ 60°C. equivalent to 2·64 volts
" " secondary . .	=	2·16 volt . . . 2·16 "
Total secondary drop . .	=	4·80 " or 2·4 volts on each side.
Mean length of magnetic ckt	=	27·5 cms.
Cross section of central core	=	8×8 = 64 × 0·93 = 59·5 effective.
" " rest of "	=	8·88×8 = 71.04 × 0·93 = 66.1 "
Assumed value of Φ	=	~~150,000~~ 226,800
Maximum " " Φ	=	~~3600~~ 3812.
Area of air gaps	=	64 sq. cms in centre, 71. sq. cms. on sides
Winding space section	=	4·125 × 4·125 = 17.016 sq. cms = 2.642 sq. ins. 1.77 actually made
I/A of magnetic ckt	=	$\frac{5}{59.5} + \frac{22.5}{66.1} = 0.084 + 0.340 = 0.4240$.
Space occupied by primary	=	700 × 0.04 × 0.04 = 1.12 sq. ins.
" " secondary	=	172 × 0.07 × 0.07 = 0.84 " "
Total space filled	=	1.96 sq. ins.
Coefficient for insulation & packing	=	1.347
Surface of iron one side	=	13 × 25.13 − 2 × 17.016 = 326.7 − 34.0 = 292.7 sq. cms
" " top	=	25.13 × 8 = 201 sq. cms
" " side	=	13 × 8 = 104 " "
Total surface of iron	=	2 × 597.7 = 1195.4 " "
Volume of iron	=	292.7 × 8 = 2341.6 × 0.93 = 2178 c.c.
Mass at sp.g. 7.8	=	17000 gms = 37.46 lbs.

Weight of transformer,				
Wire	=	5.44 lbs @ 0.20	= $ 1.088	@ $0.109 per lamp
Iron	=	37.46 " @ 0.05	= 1.873	0.187 " "
		42·90 "	= $ 2.961	0.296 " "

Primary c²r waste	=	0·65 × 0·65 × 16·76	= 7·08 Watts
Secondary " "	=	2·25 × 2·25 × 1·0	= 5·06 "
		Total loss	= 12·14 "


1 KW.T. Meter.
Curves showing the flux in different parts of the magnetic circuit under varying magneto motive forces.
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Flux.
0
1000
2000
3000
4000
5000
mmf
Flux through centre of field core
Flux passing home
Flux of useful armature flux
STANDARD CROSS SECTION. 10"x 15".

Magnetic Test of 1 KWT. Motor with 120 volt armature 13th Aug. 71

Five turns of wire were wrapped round the centre of the core, and five more under each brass where the pole pieces are attached. One coil of the armature was also disconnected and employed as a secondary.

No. of Exp.	Nature of E.M.F.	E.M.F. at terms	Capacity	Q	Mean Thickness	ϕ per div.	Resistance of G.	
8	1 Cell @ 24° C	1.4275	2 F	2.855×10^{-7}	182.8	1.562×10^{-3}	53.20	

No. of Exp.	Turns G.	Shunt	Amps	Amp-turns	MMF	No. of Reads	Mean Thick	ϕ	No. of turns	Res. added	Res. of G. incl.	ϕ	Area	$\mathcal{E}$	ρ
1		0.0963		0.0747	35.9	45.1	4	7.15	1.117×10^{-8}	5	0	5330	5953	40	149	7.53
2		0.4091		0.3172	152.2	191	4	54.8	8.966	"		"	47,800		1,195	3995
3		1.7113	0.267	1.327 1.378	648	814	3	58.9	9.202	-	25,000	30,330	279,100		6,980	2.917
4			0.585	3.019	1449	1819	4	92	14.37	-	-	"	435,900		10,890	1.67
5			0.985	5.084	2440	3064	3	113.4	17.72	-	-	"	537,500		13,440	570
6			1.920	9.91	4757	5973	3	79	12.34	-	50,000	55,330	692,600		17,060	3.502
1		0.0963		0.0747	35.9	45.1	5	10.2	1.593	10	0	5330	4,245	36.3	117	
2		0.4091		0.3172	152.2	191	4	98.6	15.41	-	-	"	41,060		1133	
3		1.7113	0.267	1.327 1.378	648	814	4	579	90.5	-	25,000	30,330			10,390	
4			0.585	3.019	1449	1819	4	159	24.84	-	"	"	376,700		10,380	
5			0.985	5.084	2440	3064	3	188.5	29.46	-	-	"	446,700		12,320	
6			1.920	9.91	4757	5973	4	117	18.28	-	50,000	55,330	505,700		13,930	
1		0.0963		0.0747	35.9	45.1	4	16.5	2.578	37	0	5330	1856 2582	19.7	185.4	
2		0.4091		0.3172	152.2	191	4	174.1	27.20	"	-	"	19,600 24,520		1960	
3		1.7113	0.267	1.327 1.378	648	814	4	188.1	28.92	-	25,000	30,330	114,500 139,320		11850	
4			0.585	3.019	1449	1819	3	142.7	22.30	-	50,000	55,330	166,200 206,300		16680	
5			0.985	5.084	2440	3064	3	157.8	24.65	-	-	-	180,300		18,430	
6			1.920	9.91	4757	5973	3	169	26.41	-	-	"	197,500		19,750	

(2) Design for a Motor-Meter to embody the claims of the original U.S. Patent # 442,901. 19th Aug. 91.

The field magnet of this instrument is in the main circuit, while the armature is supplied from a shunt in the main circuit.

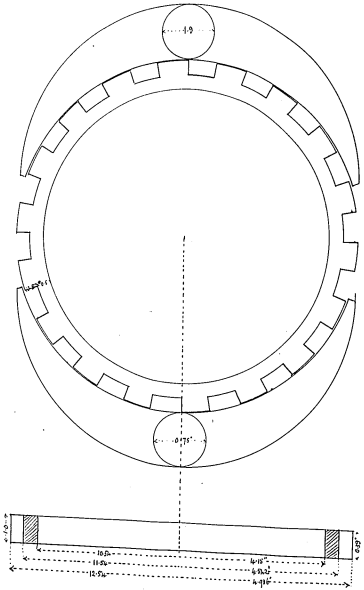
Retaining practically the same proportions as in the preceding form of motor-meter whose design appears on p. 73 Book II we obtain a Pacinotti-teeth armature 1 cm. deep and 0.5 cm. wide with teeth projecting 0.5 cm. There are 18 teeth and 18 grooves each holding 44 turns in 4 layers of 11 turns each. Since the torque on starting depends on P.D. it will be advantageous to join up each groove in two parallel halves of 22 turns each thereby increasing the current four times for a given terminal P.d., but only diminishing the effective number of wire to one half. #21. B.W.G. silk covered.

The mean turn will be 6 cms. or for 21 virtual per groove = 66 cms. and 9×11 . 99 = 100 cm of virtual res. or with commutator connections 110 = 3.6'

The drop in the field at full load should not exceed 0.25 volt at full load = (10 amperes) = 0.025 ω. Since 2 lbs. of wire can be layed on each spool, the res. per lb. is 0.025/4 @ 60°C = 0.00625 ω # 9 B.W.G. is the nearest. = 60 feet. The mean turn will be 0.45' so that there will be 130 turns in all. The smallest current being 0.5 amp, there will be 65 amp. turns. a mmf. of 80. The clearance being 1/16" = 0.04 cm. and the polar surface 7 sq. cms. the reluctance of the air gap will be 0.09 = 0.011 , and neglecting the rest of the circuit, the flux will be 7200.

Placing the two field coils in parallel, each will have a resistance of 0.05 = @ 60°C. = 0.025 - per lb. = # 12 B.W.G. = 55 feet on each spool = 120 turns . with same mmf. of 80. The air reluctance will however be 0.18 , 0.007 and the flux consequently about 10,000.

Res: of armature 0.15 ω.
Winding 4 layers of 11 turns # 21 B.W.G. 0.032" silk c. to 0.035".
Total turns 792.
Field winding 2 lbs. of # 12 B.W.G. 0.109" s.c.c. 0.117" on each spool.
Res: of each spool 0.055 - @ 60°C.
" " field (2 spools in parallel) 0.0275 - @ 60°C
Drop in field at full load 0.275 volt.



Let

C = The instantaneous current in the actn coil
c = " " " " " suspended.
T = " torsion applied for balance in ° of arc
E = " maximum emf on the alty. coil
e = " effective emf.
r = " resr. in coil with the emf.
w = " power instantaneously active in the coil
P = " total energy supplied
t = " time
α = " constant of the instrument

Then $w = \mathcal{E}\mathcal{C} = \alpha T C$

$\mathcal{E}$ = volt = $C\alpha r\, dt$

$P = \int_0^t \text{volt} = r\int_0^t Cc\, dt$

$W = \frac{r}{t}\int_0^t Cc\, dt$

$\alpha = \frac{Cc}{T}$ =

$\frac{1}{t}\int_0^t Cc\, dt = \alpha T$

$\therefore W = r\alpha T.$

Calibration of Dynamometer Wattmeter and Tests of Transformer

(73)

The dynamometer having been adjusted, the following readings were taken

No. of Obs:	Std. G. Tan:	Amp: in main coil	Current in suspended coil	amps:	Cc.	Torsion	Value of 1 div: below:	Mean
1	1·242227	0·9632	20/1035	0·01933	0·01862	360°	$5·172\times10^{-5}$	$5·20\times10^{-5}$ (amp)²
2	0·58318	0·4521	10·1/1035	0·01165	0·01883	"	$5·230\times10^{-5}$	

The dynamometer was then connected to the several transformers on no load.

No. of Obs:	Transfmr	Ratio	Torsion	R	a	RaT	rαT					
1	E.	1 KWT.	360 − 278°	17,470	$5·2\times10^{-5}$	$\frac{5·2\times17,470}{360}$	754·5					
2	T H.	0·75	" 82	18,800	"		80·2					
3	W.	1 KWT	-	17,500	-		746					

The following readings were taken next day to ascertain the efficiency of the E transformer.

Read: Obs:	T	τ	Watts in pr: coil	αT	P.D. at Sec	Lamps A	Lamps B	Total Lamps	Dynr Adj.	Current	Watts in sec:	Energy in sec	Loss	cT	Hyst: & Foucault	Comm: Eff:
1	25,920	449·5	66·7	1348	118·5	0	0	0	0	0	2·37		66·7			0·
2	27,180	99·	139·0	1·4114	118·5	1	1	2	1·2°	0·46	237	109	30			0·784
3	29,870	190°	270·4	1·502	118·	2	2	4	2·5°	0·92	236	217.	53·4			0·802
4	28,100	376°	534·3	1·1461	117·	4	4	8	6·0	1·84	231	430	119·3			0·783
5	28,800	484·5	728·9	1·498	115·5	6	6	12	10·5°	2·76	231	638	90·9			0·875
6	29,380	643·5	983·2	1·528	115·2	8	8	16	16°	3·68	230·4	848	135·2			0·862
7	29,220	786·5	1198	1·523	115·0	10	10	20	25°	4·61	230	1060	138	23	10·5	0·885

The recent ones having been found inaccurate new readings were taken

No. of Obs:	Rev.	T	αT	Watts in pr.	P.D. at Sec	Lamps A	Lamps B	Total Lamps	Dynr Adj.	Current	Watts in Sec	Loss	cT	Hyst.	Eff.
1	18.350	80°	0·9542	76·3	244	0	0	0	0	0	—	76·3			
2	18.250	177°	0·944	168	248	1	1	2	1·8°	0·46	114	54			
3	18.550	363°	0·9645	350	246	2	2	4	2·8°	0·92	226	124			
4	17.940	470°	0·9228	434	"	2	3	6	4·°	1·38	340	96			
5	18,230	585°	0·9480	555	"	4	4	8	6·30°	1·84	453	102			
6	18,290	829	0·9512	789	244	6	6	12	11·5°	2·76	678	108			
7	18,010	1085	0·9366	951	240	8	8	16	15°	3·68	893	68			
8	18,200	1286	0·9462	1273	240	10	10	20	25°	4·61	1106	167			

Field winding (shunt) for 500 volts on the 1 KWT. motor.

28 Aug. 91

A. mmf of 3500 is required from the curve of p. 71. of an exciting power of 2880 amps-turns.
With 63 watts in the field, the current can be $\frac{1}{18}$th amp. = 30,400 turns and the total resistance of the field circuit, 4000 w.
The int: diam: of winding will be 2·9" = 0·76' wire
" ext: " " " " = 4·5" = 1·178'
Mean circ: 1·95 ÷ 2 = 0·975' × 30,400 = 29,900' and at 3300 ft: per lb of wire this represents 8·76 lbs.
6 lbs: of wire will have 19,800 feet and 20,000 turns.
= 3500w. total. The resistance at 60°C. = 390 × 6 = 2340 w.
The balance should be made up (1160 w) in german silver wire exterior to the instrument. Energy expended in total field ext: = $\frac{500}{7}$ = 71 Watts of which 46·5 is in the motor and 23·5 in the resistance.

Result 2340 w @ 60°C. or 2046 w @ 20°C. of # 21 BWG. 0·030" s.c.c.
With exterior res: to make correct mmf. Weight of copper 6 lbs.

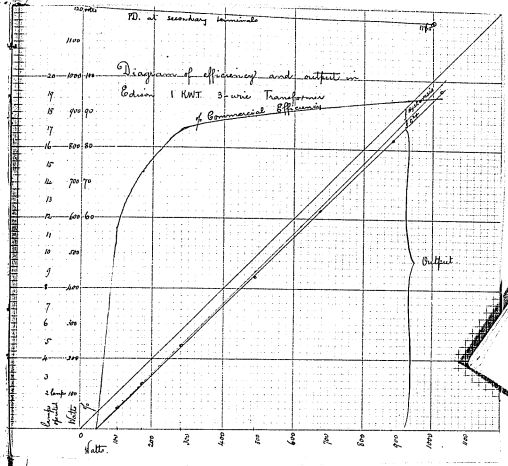
Series winding for the same motor 500-volt.

A mmf. of 1000 must be obtained at no load or 800 amp turns when 0·3 amps: passes through the machine. = 2670 turns. 2670' of wire. The full load drop with 2·37 must not exceed 27·5 v. so that the res: = 12 w @ 60°C. = 225' per w. = # 16 B+S wire 12 w of this = 1·709 × 12 = 20508 lbs: of wire.
~~12 w of~~ 2670' of # 18 BWG. = 2670 × 0·00728 = 19.42 lbs. # 18 BWG

Efficiency test of ET transformer. 22nd Aug. 91.

Conditions and connections same as those for preceding page.
20 lamps were selected, and the continuous current they took at the effective alternating pressure observed was measured to determine the energy in the secondary circuit.

No. of lbs.	+	−	Primary activity	Secondary voltage	Lamps	Total lamps	Ohms	amp	Secondary activity	Loss.	Amongst Iron	Output Amongst	Commercial efficiency
1	18,080	102	94	118	0	0	0	0	0	94	94	0	0
2	17,980	241	225	118	1+1	2	0·220	1·135	134	90	90	225	0·60
3	18,590	321	310	118·5	2+2	4	0·395	2·038	240·0	80	75	315	0·76
4	18,080	528	521	117·5	4+4	8	0·735	3·792	447	74	70	517	0·87
5	17,980	739	691	118	6+6	12	1·06	5·469	645	46	60	705	0·915
6	17,990	943·5	883	117·2	8+8	16	1·34	6·914	810	73	60	870	0·931
7	18,090	1123	1057	116·2	10+10	20	1·68	8·668	1007	50	50	1057	0·953


P.D. at secondary terminals
1150
Diagram of efficiency and output in
Edison 1 KW.T. 3-wire Transformer
% Commercial Efficiency
Output
Watts.

Efficiency Test of E Transformer

Calibration of the instrument :-

	P.D.	Res.	Ohmic	Amp/cm	τ	Energy Watts	c	Cc	α	a couplet		
1	123·25	17,700	6·685	3·535	465°	435·7	0·06962	0·02461	5.292×10^{-5}			
2	"	18,250	0·587	3·029	372°	373·3	0·06752	0·02046	5·50 .	5.25×10^{-5}		
3	124·75	18,050	0·382	1·971	261°	245·9	0·06912	0·1362	5·218 .			

Dynamometer inserted first in primary and then in secondary circuit

	R.	τ	R τ	Primary Watts	Sec. volts	Lamps		Total Lamps	Amp/cm	Secondary Watts	Primary eff.	Loss
1	18,350	45·5°	8·35	43·83	241	0	0	0	0	.		44
2	18,450	108°	19·93	104·6	240	1	0	1	0·25	60	0·57	45
3	18,600	181°	33·66	176·7	238	1	1	2	0·5	129	0·73	47
4	18,350	292°	53·58	281·3	238	2	2	4	1·0	238	0·85	43
5	18,530	503°	93·2	489·2	237	4	4	8	2·0	435	0·889	54
6	18,550	691°	128·2	673.	235	6	6	12	3·0	623	0·926	50
7	18,360	917°	168·4	884	234	8	8	16	4·0	827	0·935	57
8	18,050	1080°	195·0	1023	234	10	10	20	5·0	969	0·947	54

Dynamometer in 2nd ary circuit

No. of Wire	R.	τ	R τ	Watts		Lamps		Total Lamps				
1	18,250	144	2·625	138		1	1	2				
2	18,250	"				2	2	4				
3	17,850	464	82·84	435		4	4	8				
4	17,930	630	113·0	593		6	6	12				
5	18,100	807	148·5	777		8	8	16				
6	18,350	1005	184·5	969		10	10	20				

Weights of some samples of wire for chain weight in new form of electrolytic meter 26th Augs. 91.

40·7 cms. of phosphor-bronze wire mean diam: = 0·0213 (0·0085") weigh 0·1337 gm.
- - - - steel . - - 0·02003 (0·008") - 0·1025 .

The chain needs to be 10% heavier so that the wire has to be

$\frac{102.5}{40.7} = 2.518 \times 1.1 = 2.77$ mgms per cm.

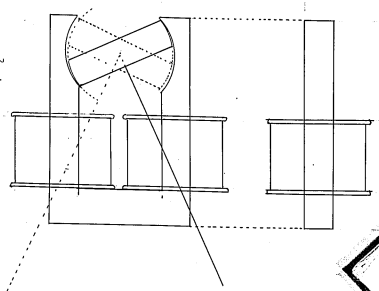
The phosphor-bronze weighs $\frac{2.77}{3.134} = 0.843$ mgms per cm. or the area must be reduced in the ratio $\frac{2.77}{3.134} = 0.843$. That is the diameter $\sqrt{0.843} = 0.918$

$0.0213 \times 0.918 = 0.01955$

Design for an alternating current ammeter.

Full size Side elevation 23rd Aug. 91.

Field and armature compound of punched wrought iron plates rivetted together.

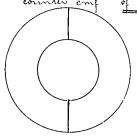


Constants of Electro Dynamometers on end table 26th-27th Aug.

Instrument # 1	Res: of right-hand coil coil:							0.0143 Ω.	Ind.	0.09 h.	@ 24°C
Instrument # 2.	a coil	198 turns	9 layers of	22	each	# 19 B&S.		0.7722 Ω	1.53 h.	@ 24°C.	
	b	20	2	10	13			0.022 Ω	0.0315 h.	"	
Instrument # 3	a	540	15	36	# 23			5.197 Ω	10.53 h.		
	b	5	1	5	# 6			0.005 Ω	0		

No. of Obs.	Obsvd.	Amp.	# 1	√	Const.	Mean	# 2	Subst.	√	Mean	# 3	√	Const.
1	0.1441	2.275	6°	2.4495	0.9288	0.9300	34°	0.3901	5.831		83°	9.1104	0.2496
2	0.572	2.952	9.5°	3.0822	0.9278		67°	0.3606	8.1854		153°	12.3693	0.2387
3	0.673	3.172	14.5°	3.8079	0.9116		81.5°	0.3826	9.027		221°	14.866	0.2336
4	0.771	3.979	18°	4.2426	0.9378		115.5	0.3703	10.745	0.3764	293	17.117	0.2325
5	0.795	4.103	18.5°	4.3011	0.9234						312	17.664	0.2323
6	1.177	6.072	44	6.6332	0.9157		35	1.026	5.9161		15°	3.873	1.568
7	1.340	6.914	59	7.6811	0.9002		49	0.9870	7.000		16	4.0	1.728
8	1.580	8.152	80	8.9443	0.9111		70	0.9744	8.3666		22	4.6904	1.738
9	1.92	9.906	118.5	10.88	0.9106		104.5	0.9694	10.22		28.5°	5.339	1.9856
10	2.25	11.61	162.5	12.747	0.9108		129.	1.022	11.3578		35°	5.9161	1.962
11	2.95	15.22	292	17.088	0.8901	0.915	257	0.9496	16.0312	0.9881	61	7.8103	1.949

On the conditions necessary for securing the maximum ratio of attractive force in alternating electromagnetic mechanisms to the counter emf of induction set up. (a) Simple harmonic currents.



Let C = the maximum cyclical current strength abs.
l = " virtual length of the magnetic act: cms
a = " area of attraction.
c = C 'inst
n = " number of turns per cm.
N = ln
ϕ = " total flux or Ba or $\int B da$.
μ_c = " permeability to the instantaneous current.
$\mathcal{E}$ = " instantaneous induction.

1st The simplest case is that of a wooden anchor ring divided by a plane passing through and perpendicular its axis. We will investigate the attraction across this plane relatively to the inductance and inductive emf. of the ring

$$\eta = N\frac{\dot\phi}{\dot c}$$
$$= \frac{N\frac{d}{dt}(4\pi c N a)}{\dot c}$$
$$= 4\pi a l \frac{N^2}{l}$$
$$\eta_m = 4\pi a C \frac{N^2}{l} p$$
$$f = \frac{1}{8\pi} B^2 a =$$
$$= \frac{1}{8\pi}\left(4\pi c \frac{N}{l}\right)^2 a$$
$$= 2\pi c^2 \frac{N^2}{l^2} a$$
$$= 2\pi C^2 \frac{N^2}{l^2}\frac{c}{C}\int_0^T \sin^2 pt$$
$$= \pi C^2 \frac{N^2}{l^2} a$$
$$\frac{f}{\eta} = \frac{\pi C^2 N^2 a l}{4\pi a C N^2 p l^2} = \frac{C N}{4 p l}$$

Therefore the current should be as strong as possible, the length of the circuit as short as possible and the frequency as low as possible.

2nd The case next in order of complexity is the same anchor ring of iron instead of wood, but laminated to avoid foucault currents:-

Then $\Phi = \frac{4\pi N}{l} c a \mu_c$ where μ is a function of c

$$\eta = N\dot\Phi = \frac{4\pi N^2}{l} a \left(\mu_c + \frac{d\mu_m}{dc}\right)\dot c$$
$$\eta_m = 4\pi a C \frac{N^2}{l} p \left(\mu_{\frac{c}{2}} + \frac{d\mu_m}{dc}\right)$$
$$f = \frac{1}{8\pi} B^2 a$$
$$= \frac{1}{8\pi}\left(4\pi c \frac{N}{l}(\mu_c)\right)^2 a$$
$$= 2\pi c^2 \frac{N^2}{l^2}\mu_c^2 a$$
$$= 2\pi C^2 \frac{N^2}{l^2}\frac{a}{T}\int_0^T \sin^2 pt\, \mu_{\frac{c}{2}}^2\, dt$$
$$= 2\pi C^2 \frac{N^2}{l^2} a\, \mu_{\frac{c}{2}}^2 \times \tfrac{1}{2} \quad \text{where } \mu_{\frac{c}{2}} \text{ is the reduced integral}$$
$$\frac{f}{\eta} = \frac{\pi^2 N^2 a \mu_{\frac{c}{2}}^2 l}{4\pi a C N^2 p l^2 (\mu_m + \frac{d\mu_m}{dc})}$$
$$= \frac{C \mu_{\frac{c}{2}}^2}{4 p l (\mu_m + \frac{d\mu_m}{dc})}$$

This expression depends on particular values of μ but as a first approximation

$$\frac{f}{\eta} = \frac{C\mu_m}{4pl}$$

The reluctance of the air gap should be as small as possible and the length of the magnetic circuit as short as possible.

Estimated Leakage Coefficient | 1·33

Total flux through field 1,570,000

"Density" in iron 9,730

Number of turns on one core 270

Current in field at no load 12·5 amp-turns = 3375 MMF 4222 × 2 for air 8000 100%

" " " " full load 15·5 " " = 4185 " 5023 "

Reluctance of air-gap at each end 0·0042 57 × 2 = 0·0085 or 8·5 millielinks.

Calculated reluctance of iron 2×0·95/85 = 0·0220 or 7/8 = 0·0115 or 11·5 millielinks.

Field winding 34 lbs of # 10 B.W.G. 0·134" s.c.c. & 0·142"

Length 630' in 273 turns on each core.

Total weight 544 lbs copper.

Loss per core 0·35 w cool. @ 20°C. 0·4 w hot @ 60°C.

Total loss in iron 6·1 w. hot 5·75 w cool.

P.D. on field at no load 75 volts. = 12·5)

" " " full " 99·6 " = 15·5)

Energy in field 937·5 watts at no load.

1440 " " full.

Power absorbed by alternator

Friction	1250 watts		1250
Eddy + Hysteresis	5350	" no load	6750 at full load.
Field	7940	" "	1440
Ext armature			1710
	7540		11,150

Commercial efficiency 30 000 / 41,150 = 0·729.

31,500 / 44,650 = 0·738

Amendments desirable in the machine.

1st More iron in the armature say 7/8" more depth making internal diam. 19·75" = 50·16

This would increase the core section by 1 cm² in 4·2 or about 22%

2nd Changing the field winding from # 10 B.W.G. to # 11 B.W.G. with thin canvas (3/4 lbs) on each spool.

3rd Reduction of body insulation to 0·05" increasing body diam: to 24·1" (61·7)

Elevation of temp: of armature on no load 100°F (55°C) giving 1150 w.

" " field " " " 73°F (40·5°) " "

" " armature " " " 70°F (39°C) " 1050

" " field 70°F (39°C) " "

Inductance of armature 7 h.

(a) Data of Edison 500-lt. alternator as completed and amended. (78)

Gramme ring armature 16 poles.

Power 30 Kilowatts at 30 amperes at 1000 volts effective.

Lamps 500 of 16 cp and 50 watts each = 25 KWTs.

Speed = 1060 revs: per min: 17·6 rps.

= 6800 ft. per min: peripheral speed 3405 lin: = 113·3 ft per sec. or

= 4729 " " belt speed 2340 " = 78·6 " "

Frequency = 16 alternations or 8 wpair: revs = 141 per sec:

= 19000 alternations or 8500 ~ cycles per minute.

b = 889·6 say 890

Dimensions (of body) = Internal diameter 20·5" = 52 cm } Cross section of body 4·625 × 27·9 × 0·8 = 99·4 sq ins:

External diam: = Body 24·" = 60·96 } 1·75 × 11 = 19·25 " "

Over insulation = 24·2" = 61·46

Over conductor = 24·42" = 62·02

" binding wire = 24·44" = 62·23 Volume of iron in armr: 17750 c.c. besides bolts and side plates.

Exterior of binding = 24·75" = 62·87

" field = 24·94" = 63·36

" frame = 40·67 = 103·3

Exterior " " = 46·67 = 118·5

Thickness of plates = 0·012 / 0·027 = 0·030 / 0·035

Breadth of body = 11" = 27·9

Over side arms = 12·7" = 32·3

" Conductors = 13" = 33·0

Clearance = 0·125" = 0·318

Entrefer = 0·375" = 0·952

Width of poles = 2·5" = 6·35

Breadth " " = 10" = 25·4

Thickness of plates = 0·125" = 0·317

Distance between poles = 2·3" = 5·84

Number of plates in field = 640.

Weight of iron in magnets = 1800 lbs.

" " Armature = 305 lbs + bolts + side plates say 350 lbs (138·6 Kgm + 7% 158·8 Kgms)

Body insulation = 0·1" = 0·254

Winding = 512 turns of # 13 B.W.G. 0·095" d.c.c. to 0·110" in one layer of 16 segments, the segments being connected in succession. The two adjacent ends to be carefully insulated and separated.

Max: EMF = 1200 volts effective = 1696 max: say 1700

= 1675·0 " " = 106/27 = 3·925 " in each segment

= 2·364 " " = 3·346 " " turns.

Area of wire = 9025 cmils = 300·8 cmils per amp. effective.

Length " = 1150'

Res: at 20°C = 1·75Ω Drop at full load 4·25 v.

" " 100° = 1·97Ω. " " " 5·9 v.

Weight of iron = 31·4 lbs.

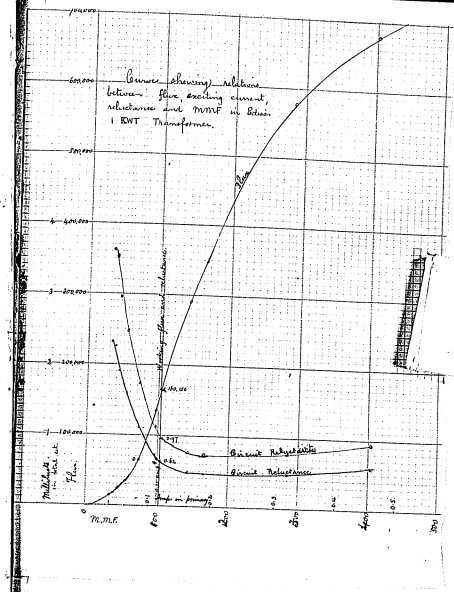
Drop due to inductance = 65 volts.

Magnetic flux = 1,180,000 through each pole

Induction through = 1,180,000 / 99·4 × 2 = 5900 in iron and 7940 round bolts.

Hysteresis per cycle = 2650 ergs in iron = 4100 ergs mean bolt hole

= 664 watts in whole armature at 5900 lines.


(Curves showing) relations
between flux, exciting current,
reluctance and MMF in Ratio
1 KVT Transformer
Flux
Ratio of flux and reluctance
Exciting current in Amperes
M.M.F.
Ratio
Reluctance

Test of Magnetic Circuit of 1 KWT. Edison Transformer.

5 turns of wire wrapped round central core over the ~~wire~~ secondary coil and taken to the ballistic galvanometer. Primary coil employed.

No of Obs.	Std. Turns	Amp. $\times 10^{-1}$	Amplitude	Mom^{t} Const	No. of Throws	Mean Throw	Resistance	Ind. Coil	q 10^{6}	ϕ	$\mathcal{E}$ max.	γ $\times 10^{-3}$	μ 10^{-3}
1	0.04803	0.03722	26.06	32.75	5	16.8	0	5350	2.641 X	114,070	244	2328	3.628
2	0.05824	0.04514	31.6	39.71	5	21.0	"	"	3.289	17,570	305	2.2580	3.519
3	0.08554	0.0588	35.56	44.69	5	28.1	"	"	4.401	23,520	408	1.898	2.958
4	0.07870	0.0610	42.7	53.66	5	40.3	"	"	6.311	33,760	585	1.590	2.478
5	0.10510	0.08147	57.014	71.68	5	77.3	"	"	12.11	64,800	1123	1.106	1.724
6	0.14054	0.1089	76.24	95.81	5	160	"	"	25.06	134,100	2325	0.7144	1.113
7	0.14905	0.1158	81.06	101.9	5	197	"	"	30.85	165,000	2861	0.6175	0.9622
8	0.28800	0.1612	112.8	141.8	5	120.6	18,000	15,350	18.89	290,000	5028	0.4889	0.7618
9	0.24098	0.1861	130.3	163.8	5	145.5	"	"	22.79	349,800	6066	0.4693	0.7298
10	0.41660	0.3229	226.	284.0	5	121.4	25,000	20,350	19.01	577,000	10000	0.2932	0.7670
11	0.58905	0.4566	319.6	401.6	5	143	"	"	22.40	679,800	11,790	0.5908	0.9208
12	1.62813	1.265	885.4	1112.	5	97.3	52,000	55,350	15.24	814,500	14,630	1.319	2.056
13	2.71062	2.101	1471.0	1849.	4	107	"	"	16.76	927,800	16,090	1.993	3.106

No. of Obs.	Source of EMF	EMF at temp.	Capacity	q	Mean Throw	γ per div^{n}
12	1 C.C. @ 24.5°C 1.427	1.427×10^{6}	2×10^{-11}	2.852×10^{7}	182.23	1.566×10^{-7}

Final Test of Transformer 1 KWT model before delivery

The weight of the transformer body with clamps = 60½ lbs.
" " " in case complete = 180 lbs.

It was placed upon the alty. current circuit at 20 cel. 3rd Depth and operated at full load until 12 on the 4th = 16 hours.

The temps of the external surface of the case were then 39°C 16th cir
" " " transformer coil surface " " 49° C 26th cir
" " " air 21.3°C

External diameter of shell cylinder 10 7/8" over flanges 9¾" inside flanges 9"
Internal " " " " "
Length internal " " " 13 7/8"
" external " " " over all 15"
Depth of free box chamber 1½".

Rev. 8 = hot primary after 16 hr load.

Drop at full load 3.75 volts on each side.

No. of Obs.	P.D.	Ohmic	Amps.	Energy in watts	Current in field	Energy in field	Current in armt.	Energy in armt.	Rev. of armt.	Drop in armt.	Energy lost in armt.	E.M.F. armt.	Speed rpm
1	504		0·133	67	0·133	66·9	0		22·64	0	0		1600
2	504	0·075	0·387	195	"	"	0·254	128	"	5·8	1·5	498·2	"
3	504	0·085	0·439	221	"	"	0·306	154	"	7·0	2·1	497	"
4	506	0·110	0·568	288	"	"	0·435	221	"	9·9	4·3	496	1580
5	504	0·144	0·722	364	"	"	0·589	297	"	13·7	10·8	488·3	1570
6	580	0·151	0·779	452	0·152	88	0·627	364	"	14·3	9·0	565·7	1700
7	562·4	0·140	0·980	571	"	"	0·828	483	"	18·9	15·6	563·5	1690
8	580	0·245	1·160	673	"	"	1·005	585	"	23·0	23·2	586·8	1685
9	571	0·245	1·522	869	"	"	1·370	781	"	31·2	42·8	528·3	1655
10	571	0·378	1·910	1091	"	"	1·758	1003	"	40·1	70·5	500·5	1600
11	575·4	0·430	2·22	1277	"	"	2·068	1189	"	47·2	97·5	477·9	1600
12	575·4	0·460	2·374	1366	"	"	2·222	1278	"	50·7	112·6	462·8	1585
13	573	0·460	2·374	1360	"	"	2·222	1272	"	50·7	112·6	460·4	1605

Curves showing ρ with respect to π on two scales for Wainright and cast iron taken from Hopkinson's results.

Cast iron

Cast iron to next scale

Wainright iron

Wainright iron to next scale

Final Test of Edison 500 volt 1 KWT shunt Motor on 575 volts 31st Aug. 91.

Temps. on commutator after 4 hours 110°F. air 70°F. 43·3°C. 21·1°C.
a rise of 40°F. or 22·2°C.

Field

Armature C.W.

Friction

Delivery

Electrical efficiency

Commercial efficiency

Shunt Amps.

Watts

STANDARD CROSS SECTION. 10mm No. 80.

On some Relations between H and ρ in Iron discovered 27th Aug. 80

...ving observed that the curve of ρ on page 31 between the limits H=5·52 ... apparently a straight line while from H=1 to H=3 it is also nearly ...aight it was decided to analyse some of Hopkinson's results to test ... relationship. Vide Jamieson pocket book p. 380 & by. Silv. Thompson.

No.	B.	H	μ	ρ	αH	β	Calculated	Δρ	% Error	Δαx	ratio ρ/H this
	5000	2	2500	0·0004	0·0001165	0·00022	0·000,3165	+0·000,0835	65·8	0·0001534	0·242
2	9000	4	2250	0·0007444	0·000,2330		0·000,4336	+0·000,0664	2·1		1·021
	18,000	5	2000	0·00050	0·000,2910		0·000,5120	+0·000,0120	2·4		1·0244
	11,000	6·5	1692	0·000591	0·000,3787		0·000,5997	+0·000,0007	1·5		1·015
	12,000	8·5	1412	0·0007502	0·000,4961		0·000,7164	+0·000,0016	1·2		1·012
	13,000	12	1083	0·0009233	0·000,7008		0·000,9208	+0·000,0008	0·28		0·9972
	14,000	17	823	0·001,251	0·000,9929		0·001,2128	−0·000,0002	0·2		0·9928
	15,000	28·5	526	0·001,911	0·001,665		0·001,885	−0·000,065	0·86		0·9914
	16,000	52	308	0·003,2468	0·003,037		0·003,257	+0·000,010	0·32		1·0032
	17,000	105	161	0·006,212	0·006,132		0·006,352	+0·000,140	2·3		1·023
	18000	200	90	0·01111	0·011,660		0·011,900	+0·000,79	7·1		1·071
	19000	350	54	0·01852	0·026,05		0·020,67	+0·002,015	11·6		1·116

Final Test of 500-volt 1 KW.T. Motor 31st Aug. 81.

Amps.	Speed r.p.s.	Brush pressure lbs. per sq. inch	Effort	Balance	Moment	Gibb Moment	Deltring	Dynamo (P.D.)	Dynamo amperes	Energy	Eff.	Eff.
	~~26·6~~							0				
8	26·6	6·00	126·5									0·649
3	"	6·00	152	250 @ 10	2500	1·5442	41·				0·185	0·698
9·5	26·3	6·00	216·7	250 @ 25	6250	3·8574	101·5				0·352	0·753
7·5	26·16	6·00	286·2	" @ 47	11,750	7·2444	189·5				0·520	0·786
98·7	28·3	6·00	355	" @ 67	11,750	7·2444	205·3	116	1	116	0·454	0·785
19	28·16	6·00	467·4	500 @ 35	17,500	10·790	304·	116	1·7	197	0·532	0·818
35·4	28·08	6·00	561·8	500 @ 45	22,500	13·87	389·6	113	2·5	283	0·579	0·835
58·3	27·6	6·00	738·2	1000 @ 30 250 @ 30	38,000	21·58	595·7	109	4	436	0·686	0·849
5	26·6	6·00	932·5	1000 @ 40 250 @ 50	41,250	25·43	678·	107	5·5	588	0·622	0·855
7·2	26·6	6·00	1091·5	1000 @ 50	50,000	30·83	821·8	105	7·0	735	0·643	0·855
03	26·4	6·00	1165·4	1000 @ 50 500 @ 10	55,000	33·9	895·	103	7·7	793	0·655	0·853
85	26·75	6·00	1159·4	1000 @ 50 250 @ 10 250 @ 45	54,750	31·29	887·2	102	8·3	850	0·625	0·853

Prepare winding for 240 volts 10 layers of 7 turns each + 4 extra turns on 4th = 74 turns in all # 21 B&S 0.032" dec. to 0.041"
72 conds turns.

PARTICULARS AND DATA OF EDISON MODEL 1 KILOWATT MOTOR.

Type Crown field armature with Pacinotti teeth.
Power 1 kilowatt.
Voltage 120 and 500.
Current 8.3 amperes at 120 volts, 2 amp. at 500 volts.
Total weight with pulley 114 lbs. or 9 watts per lb.
Speed :- On 120 volts 1500 rpm. Light 1550 loaded.
On 500 volts 1600 rpm. Light 1650 loaded.
Peripheral speed of armature 3000 ft. per min. to 3250.
Belt speed 1600 to 1800 ft. per min.
Dimensions:-
Length over all 14 1/2"
Breadth over all 14 1/2"
Height over all 14 1/2"
Pulley 4" x 3" one flange.
Armature:- Internal core diameter 4.4"
External diameter of core proper 6.9"
Depth of core proper 1"
Breadth of core 1.75"
Cross section of core 1.75 sq. in.
Diameter of groove cover circle 7.2"
External diameter of armature 7.5"
Polar core diameter 7.35"
Depth of grooves 0.45"
Breadth of grooves 0.4"
Thickness of groove cover 0.05"
Width of ends 0.06"
Thickness of full dividing grooves 0.4" above 0.22" below.
Ends for 0.015"
Armature plates assembled without paper.
NB. The 500 volt armature was assembled with paper insulations experimentally, procuring 100 revs. per min. higher speed.
Number of grooves in armature 36
Commutator diameter 2.5"
Commutator length 1.4" might be increased to 1.75" with armature.
Number of coils 36 for 120 volts. 72 for 500 volts.
.·. The 120 volt commutator was built with 2 bars experimentally but afterwards connected in pairs.
Field Space in cast steel Core diameter 2.03"
inner over shunt winding 4.7"
Interflange 1.1"
Armature winding for 120 volts 7 layers of 5 turns each with 2 extra turns on top or 37 turns in each groove
1332 turns all round armature
16 B&S. 0.060" dec. to 0.064"
Res. of armature hot between brushes 1.01 ohm.
Drop in armature at full load 10.3 volts.
Energy lost in armature wire at full load 72 watts.
Commutator connections of copper silver 2.4" of # 22 B&S.

Armature winding for 500 volts:-
15 layers of ten turns plus 7 extra turns on top or 157 turns in all per groove. Total 4455 turns on armature
(29 S.W.G. 0.0700" d.c.c. to 0.013"
Resistance of armature in lok between brushes 21 ohms.
Drop in armature at full load 40 volts.
Energy lost in armature wire at full load 12 watts.
Current for connections 7.5" of 3/16 1% German silver wire.
Armature winding suggested for 250 volts.
10 layers of 7 turns plus four extra turns on top or 74 turns in each groove.
21 S.W.G. 0.032" d.c.c. to 0.034" 72 commutator bars.
Field winding for 500 volts:-
1lbs. 1½ oz. of 7/64 B.W.G. 0.010" sec. in about 20,000 turns resistance 2400 ohms. In circuit with this 1700 ohms of german silver wire 7/64 B.W.G. on frame
Proposed shunt winding for 250 volts:-
5 lbs. of 7/64 B.W.G. 0.01-" making 600 ohms with 500 ohms of 3/64 B.W.G. german silver resistance under in circuit
Winding suggested for 120 volts.
3½lbs. of 3/64 B.W.G. 0.013" making 80 ohms wire.
Loss of energy in 500 volt field circuit 25 watts.

Particulars and Data of Edison 1 Kilowatt Motor before Delivery 1st Sept.

Type	Gramme ring	Pacinotti Teeth	punched plate armature		
Power	1 Kilowatt		2 brushes above + 2 below.		
Voltage	120 volts		500 volts		
Current	8.5 amp.		2 amp.		
Weight with pulley	113 lbs.	51.25 kgms.	= 9 watts per lb.	19.5 watts per kgm.	
Speed	on 120 volts 1500 r.p.m. 25 ft.s.	Light, 1250 r.p.m. 20.83 ft.s.	Loaded. " "	Pulley 4" Face 2"	Box side Pumps.
	" 500 - 1600 r.p.m. 26.6 ft.s.	light 1400 r.p.m. 23.3 ft.s.	" "		
Diagonal speed of arm	on 120 - 2980 ' p.m.	light 2405' p.m.	- -		
	- 500 - 3142 ' -	- 2750' -	- -		
Belt speed.	- 120 - 1570' -	- 1310' -	- -		
	- 500 - 1676 -	- 1167' -	- -		

Dimensions — Length over all 12½", Breadth 12½", Height 12½". Shaft 0.625"

Armature		
Internal core diameter	4.4"	
External - -	6.4"	
Depth of core flange	1.0"	
Diam of slot circle	7.32"	
External core diam:	7.5"	Polar bore 7.53"
Depth of box	0.46"	1.17
Width - -	0.34"	0.86
Iron Thickness	0.07"	
Gap	0.008"	
Width of armature	1.73"	
Iron section of core	1.75 sq. ins.	
Cable Thickness	0.5"	above, 0.22" below.
Diameter	0.015"	
Field Cast Steel frame Segmental		
Core diameter	2.812"	
Diameter over pole pieces (pole)	4.7"	
Interflange	6.6"	
Diameter of counter	2.5"	
Length - -	1.4"	
Number of bars	36 for 120 volts 72 for 500.	
Number of grooves in arm	36	

Winding for 120 volts: 7 layers of 5 turns each + 2 extra turns on top = 37 turns per groove = 1332 turns in all # 18 B.W.G. 0.049" d.c.c. 0.064".
Res: of arm = 1.01 ω Ext. between brushes.
Drop in - = 8.5 volts at full load.
Energy - = 72 watts - - -
Conts: commutator segments silver = # 22 B.W.G. 0.025". 2.3" long.

Winding for 500 volt = 15 layers of 10 turns each + 7 extra turns on top = 157 turns per groove = 4452 turns in all # 25 B.W.G. 0.020" d.c.c. 0.031".
Res: of arm = 23 ω Ext between brushes
Drop in - = 46 volts at full load.
Energy = 92 watts - - -
Conts: commutator G.S. = 2.8" # 26 B.W.G. 0.019".

500 volt armature body was assembled with paper interleaves. The 120 volt armature was rejected.

Field winding for 500 volt, (6 lbs. 14 oz.) of # 31 B.W.G. 0.010" d.c.c. 0.0 in about 20,000 turns. 2050 ω @ 20°C. and 1725 ω of external res: of #35 B.W.G. G.S. s.c. wire in series. Total res: 3800 ω warm.

Proposed shunt winding for 120 volt = 5 ½ lbs: of # 26 B.W.G. 0.018". @ 37.1 ω per lb = 204 ω @ 60°C.
126/204 = 0.67 of 1020' per lb. = 5600 turns = 1960 ft.

Proposed shunt winding for 240 volt = 5 lbs: of # 28 B.W.G. 0.014" @ 181.4 ω per lb = 907 ω with 2000 of #33 B.W.G. S.C. wire = 707 ω = 3/4 = 0.34) and 1680' per lb = 8400 turns = 2800 ft.

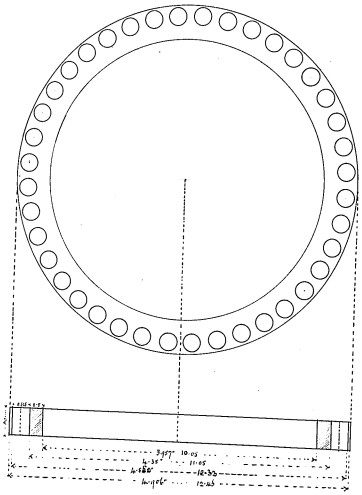
Efficiency Test of Thomson-Houston 15 Kt Transformers.

The primary of the transformer was operated at 1000 volts eff. pd and the secondary closed through 60 volt lamps and one #1 dynamo. For a description of the transformer, see p. 82.

Repaired Transformer

No. of Obs.	R	T	RT	Pr. Watts 5.25×10⁴	Comt	Dynm.	J	Amp. 0.915	Volts at terminals	Watts	Efficiency	Loss
			10⁴									
1	17600	78°	1373	72.1	0	0	0		52	0		72.1
2	18,600	116°	2.157	113.2	·1 λ	"	0		"	42·2	0·382	70
3	"	176°	3·310	173·8	3 λ	3·0	2·236	2·16	50·5	109.1?	0·627	64.7
4	18,360	255°	4·682	245·8	6 λ	14·6	3·80	3·477	49	170·4	0·693	75·4
5	18,600	333	6·193	325·2	9 λ	27·8	5·273	4·826	48	231·7	0·712	93·5
6	18520	447	8·278	434·6	12λ	56·5	7·517	6·878	50	343·9	0·791	90·7
7	18,220	536	9·766	512·8	15λ	81,	9·0	8·236	49·5	407·8	0·795	105·0
8	15,350	624	11·45	601·2	19 λ	115·	10·724	9·810	49·1	488·2	0·799	121·0
9	15,190	781	14·44	758·2	24 λ	162.	12·767	11·68	48·25	563·5	0·743	194·7
10	18,350	960	17.62	925·0	29 λ	247.	15·716	14·38	47·8	687·4	0·743	237·6

No. of Obs.	R.	T	RT	Pr. Watts 5.25×10⁴	Comt	Dynm.	J	Amp	Volts at terminals	Watts	Efficiency	Loss
			10⁴									
1	17.900	81·5°	1·459	76·6	0				50			76·6
2	17.600	123·	2·165	113·6	1 λ	1	1	0·915	49·5	45·3	0·399	68·3
3	18,550	177°	3·283	172·4	3	4	2	1·830	49·5	90·6	0·526	81·8
4	18,050	251°	4·530	237·9	6	13	3·606	3·30	49·7	164·1	0·690	73·8
5	18,210	330°	6·010	315·6	10	33	5·745	5·257	49·5	260·2	0·824	55·4
6	17.910	477°	8·542	448·5	13	56	7·483	6·848	49.	335·6	0·748	112·9
7	18,050	559°	10·09	529·7	17	88	9·381	8·584	48·	412·0	0·778	117·7
8	17.950	633°	11·36	596·3	21	126	11·225	10·3	47.6	490·2	0·822	106·1
9	18,290	721°	13·19	692·5	25	175	13·229	12·105	47·5	575·4	0·830	117·5
10	18,290	853°	15·69	823·6	29	231	15·199	13·90	47·9	665·8	0·808	157·8



Area of external armature coils 12.2 sq. cms
" " internal " 7.93 "
" " annulus " 42.69 "
" " one drill hole 0.7166 "
" " 40 " 12.664 "
" " iron armature 30. sq. cms.
Volume " 30 c.c.

As constructed 16. IX. 91. Ext. diam 4.98"
Int. " 3.957

New Design for a Motor-Meter.

(83.)

The motor whose design is given on page 72, failed to start at a fair limit of current owing to the small number of teeth. The design on the opposite page was therefore 'indicated'.

The starting torque of a motor whose armature lies symmetrically in the field consists of two parts friction and forward hysteresis. Let the frictional starting torque be f

Let $\mathfrak{H}$ be the maximum flux density
$\mathfrak{h}_g$ " " hysteresis exp/sec. = $\mathfrak{H}\eta_g$
v_g " " volume of iron in armature
h " " torque due to hysteresis

Then $v_g = 2.8\,h$
$h = v_g/2\pi$
$T = f + v_g/2\pi$.

with $v = 30$ and $\eta_g = 12,000$ $h = 360,000/2\pi = 57,290$ dyne cms.
$= 57.3$ gm. cms.

The frictional moments were observed on the 11th Sept: 91. as follows

Friction of centre 2.65 cms gms
Brushes lightly resting 7.67 " "
" resting strongly 12.01 " "

The total force to overcome if $\eta_g = 4,000$ will be 42 gm. cms. moment.

If a be the effective area in one groove for copper wire (sq. cms)
$\mathfrak{E}$ " " emf at armature terminals " acmw
c " " current in the armature " acmw
r " " resistance of " acmw
w " " number of wire all round
α " " " " in one hole
ρ " " resistivity
l " " length of one turn (mean)
The resistance of one groove will be $\frac{l\alpha^2\rho}{a}$
" " the armature " $\frac{\frac{1}{2}l\alpha^2\rho}{a}$
" current in " $\frac{4\mathfrak{E}a}{l\alpha^2\rho}$
" starting torque " if full " $\frac{4\mathfrak{E}a}{l\alpha^2\rho}\cdot\frac{1}{2\pi}\cdot\varphi\cdot\pi = \frac{2\mathfrak{E}a}{l\eta_g\alpha^2\rho}$

This diminishes with increasing α, so that the resistance of the armature should be kept low. On the other hand, a very low resistance in the armature would produce uncertain results with the least variation of brush resistance. If therefore #19 B.W.G. wire be adopted this being the largest size we have with covered, 0.042" cond to 0.049"

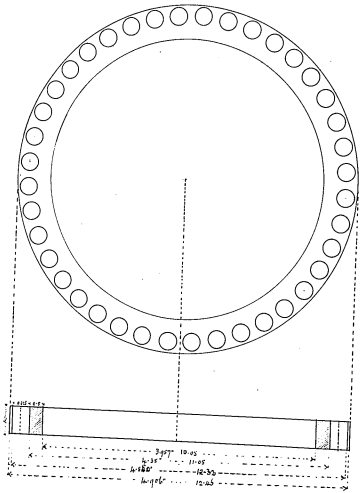
The holes are 0.250" with a sleeve of fibre 0.010 leaving a diameter of 0.230
This is an area of 0.04115 sq. ins. while the wire is $(0.048)^2 = 0.00230$ sq. ins.
Ten wire will fit into the groove but probably only 9 in winding the lengths being 1.3' = 0.164' per turn. The total length of wire on the armature will be 52 feet and 360 turns. The resistance = 0.076 ω. with brushes say 0.1 ω. With 0.025 volt this means 0.25 amp and $\varphi = 10,000$ $w = 360$
the torque = $\frac{2500\times360}{6} = 150000 = 150$ cms gms.
With #20 B.W.G. 0.035" and 0.028" 17 turns go in each groove 2.5' = 100 feet of wire in all at 0.0014 ω per foot = 0.14 ω + 0.21 ω. With brushes say 0.25 ω. and with 0.025 volt = 0.1 amp $\varphi = 10,000$ $w = 680$ the torque $= \frac{1000\times680}{6.85} = 100,000 = 100$ cms gms.

Efficiency Test of Thomson-Houston 15 Kl Transformers.

The primary of the transformer was operated at 1000 volts eff. pd and the secondary closed through 60 volt lamps and one #1 dynamo. For a description of the transformer, see p. 80. Repaired Transformer

No. of Obs.	R	T	RT	Pr. Watts 525×10	Load	Dynamo	I	amp. 0.915	Volts at lamps	Watts	Efficiency	Loss
1	17600	78°	1373	72·1	0	0	0		52	0		72·1
2	18,600	116°	2·167	113·2	·1 λ	"	0		"	43·2	0·382	70
3	"	178°	3·310	173·8	3 λ	8.0	2·236	2·16	50·5	109·1?	0·627	64·7
4	18.360	255°	4·682	245·8	6 λ	14.6	3·80	3·477	49	170·4	0·693	75·4
5	18,600	333	6·193	325·2	9 λ	27·8	5·273	4·826	48	231·7	0·712	93·5
6	18.820	447	8·278	434·6	12 λ	56·5	7·517	6·878	50	343·9	0·791	90·7
7	19.220	536	9·766	512·8	15 λ	81,	9·0	8·236	49·5	407·8	0·795	105·0
8	18,350	624	11·45	601·2	19 λ	115.	10·724	9·810	49·1	488·2	0·799	121·0
9	18,490	781	14·44	758·2	24 λ	162.	12·767	11·68	48·25	563·5	0·743	194·7
10	18.350	960	17.62	925·0	29 λ	247.	15·716	14·38	47·8	687·4	0·743	237·6

No. of Obs	R.	T	RT	Pr. Watts 525×10	Load	Dynam.	I	amp	Volts at terminals	Watts	Efficiency	Loss
1	17.900	81·5°	1·459	76·6	0				50			76·6
2	17.600	123°	2.165	113·6	1 λ	1	1	0·915	49·5	45·3	0·399	68·3
3	18,550	177°	3·283	172.4	3	4	2.	1·830	49·5	90·6	0·526	81·8
4	18,650	251°	4·530	237·9	6	13	3·606	3·30	49·7	164.1	0·690	73·8
5	18,210	330°	6·010	315·6	10	33	5·745	5·257	49·5	260·2	0·824	55·4
6	17.910	477°	8·542	448·5	13	56	7·483	6·848	49.	335·6	0·748	112·9
7	18,050	559°	10·09	529·7	17	88	9·381	8·584	48.	412·0	0·778	117·7
8	17.950	633°	11·36	596·3	21	126	11·225	10·3	47.6	490·2	0·822	106·1
9	18,290	721°	13·19	692·5	25	175	13·229	12·105	47·5	575·4	0·830	117·5
10	18,390	853°	15·69	823·6	29	231	15·199	13·90	47·9	665·8	0·808	157·8



Area of external armature circle 122 sq.cms
" internal " 79.33 "
" annulus " 42.67 "
" one drill hole 0.9168 "
40 " 12.664 "
" iron armature 30. sq.cms.
Volume " 30 c.c.

As constructed 16. IX. 91. Brk: diam 4.95"
" Brk. 3.937

New Design for a Motor-Meter.

(83)

The motor whose design is given on page 72, failed to start at a fair limit of current owing to the small number of teeth. The design on the opposite page was therefore 'indicated'.

The starting torque of a motor whose armature lies symmetrically in the field consists of two parts friction and forward hysteresis. Let the frictional starting torque be f

Let $\mathfrak{H}$ be the maximum flux density
y " " - hysteresis exp factor. = $\mathfrak{H}^{1.6}$
v " " volume of wire in armature
h " " torque due to hysteresis

Then $v\,y = 2\pi h$
$h = v\,y/2\pi$
$T = f + v\,y/2\pi$.

with $v = 30$ and $y = 12{,}000$ $h = 360{,}000/2\pi = 57{,}290$ dyne cms.
$= 57.3$ gm. cms.

The frictional moments were observed on the 11th Sept: 91. as follows

Friction of centre 2.65 cm gms
Brushes lightly resting 7.67 "
" resting strongly 12.01 "

The total force to overcome if $y = 4{,}000$ will be 42 gm. cms. moment.

If a be the effective area in one groove for copper wire (sq. cms)
e " " emf at armature terminals acmvs
c " " current in the armature acmvs
r " " resistance of " acmvs
w " " number of wires all round
α " " " " in one hole
ρ " " resistivity
l " " length of one turn (mean)
The res: of one groove will be $\frac{6\alpha^2\rho}{4a}$
" " the armature " $\frac{6\alpha^2\rho}{4a}$
" current in " $\frac{4es}{6\alpha^2\rho}$
" starting torque " if full " $\frac{4es}{6\alpha^2\rho} \cdot \frac{1}{2\pi} \cdot \mathfrak{H} \cdot y\pi = \frac{2es\mathfrak{H}}{3\alpha^2\rho}$

This diminishes with increasing α so that the resistance of the armature should be kept low. On the other hand, a very low resistance in the armature would produce uncertain results with the least variation of brush resistance. If therefore # 19 B.W.G. wire be adopted this being the largest size we have silk covered, 0.042" and to 0.029

The holes are 0.250" with a sleeve of fibre 0.010 leaving a diameter of 0.230
This is an area of 0.01415 sq. ins. while the wire is $(0.042)^2 = 0.00230$ sq. ins.
Ten wire will fit into the groove but probably only 9 in winding the lengths being 1.3' = 0.144' per turn. The total length of wire on the armature will be 52 feet and 360 turns. The resistance 0.076 w. with brushes say 0.1 w. With 0.025 volt this means 0.25 amp. and $\mathfrak{H} = 10{,}000$ $w = 360$
the torque $= \frac{2500 \times 360}{6} = 150000 = 150$ cms. gms.
With # 20 B.W.G. 0.035" d.c.c. 0.038" 17 turns go in each groove 2.5' = 100 feet of wire in all at 0.00810 w per foot = 0.81 w. $\frac{1}{4} = 0.21$ w. With brushes say 0.25 w. and with 0.025 volt = 0.1 amp $\mathfrak{H} = 10{,}000$ $w = 680$ the torque $= \frac{10000 \times 680}{6.25} = 100{,}000 = 100$ cms gms.

The formula given by Rowland as expressing his observations is

$$\mu = M \sin\left(\frac{b + \gamma\mu + \beta}{\gamma}\right) \quad \ldots \text{ (1) where } M \text{ is the max. value of } \mu$$

$$\therefore \quad I = M \cos\left(\frac{b + \gamma\mu + \beta}{\gamma}\right)\left(\frac{H+a}{l}\right) \qquad \text{because } \frac{dB}{dH} = H \quad (B = \mu H)$$

$$\mu^2\left(\frac{H+a}{l}\right)^2 = M^2\left(\frac{H+a}{l}\right)^2 \qquad \text{but } M\mathfrak{R} = \frac{B_{max}}{H} = \frac{H}{4\pi H} = \frac{1}{4\pi}$$

$$\therefore \mu^2 + \left(\frac{\gamma}{H+a}\right)^2 = \frac{1}{a^2}\left(\frac{H+a}{l}\right)^2$$

$$\therefore \quad \mu^2 = \frac{1}{a^2} - \left(\frac{\gamma}{H+a}\right)^2 \qquad \ldots\ldots (2)$$

and $$\mu^2 = M\mathfrak{R}^2 - \left(\frac{\gamma}{H+a}\right)^2 \qquad \ldots\ldots (3)$$

Assuming that between H = 0 and H = critical force $\rho = \alpha - \beta H$

$$B = \frac{H}{\alpha - \beta H}$$

$$\frac{dB}{dH} = \frac{\kappa}{(\alpha - \beta H)^2} = \frac{\alpha}{\rho^2} = \alpha(\mu - 1)^2$$

Consequently for a given small change in H the variation in B will vary directly with the square of the initial permeability existing, & inversely as the square of the existing reluctance.

Also assuming that from H = critical value to $H = \infty$ $\rho = \alpha + \beta H$

$$B = \frac{H}{\alpha + \beta H} \quad \frac{dB}{dH} = \frac{\alpha}{(\alpha + \beta H)^2} = \frac{\alpha}{\rho^2} = \alpha(\mu - 1)^2, \text{ the same law.}$$

And $$H = \frac{aB}{1 - bB} \qquad \text{but } \frac{B}{H} = \mu - 1$$

$$\therefore \quad \frac{B(1 - bB)}{aB} = \mu - 1$$

$$\text{or } \frac{1}{a} - \frac{b}{a}B = \mu - 1$$

$$\therefore \mu = c - dB$$

consequently a linear relation should subsist between μ and B or κ and I except at the critical point.

On the relations between Magnetic Force and Magnetic Induction. (84)

If R be the reluctance of an elementary volume of magnetic material + ether
ρ " " " " " " alone
H " " magnetic force
I " " induced magnetisation.
B " " total induction
κ " " coefficient of induction
μ " " permeability $= 1/\kappa$

Then

$$\frac{B}{4\pi} = \frac{H}{R} \qquad \ldots\ldots (1)$$

$$4\pi I = \frac{H}{\rho} \qquad \ldots\ldots (2)$$

$$= \frac{H}{\alpha + \beta H} \qquad \ldots\ldots (3)$$

$$\therefore \quad \rho = \alpha + \beta H \qquad \ldots\ldots (4)$$

$$4\pi\kappa = \frac{1}{\rho} \qquad \ldots\ldots (5)$$

$$\frac{1}{\kappa} = 4\pi(\alpha + \beta H) \qquad \ldots\ldots (6)$$

$$\rho = \frac{R}{1 - R} \qquad \ldots\ldots (7)$$

$$R = \frac{\rho}{1 + \rho} \qquad \ldots\ldots (8)$$

$$\frac{\rho}{R} = \frac{B}{B - H} \qquad \ldots\ldots (9)$$

The following is an example of observations by Shelford Bidwell communicated to the Royal Society 20th May 86.

Ref No.	H	ΔH	I	μ	B	κ	1/κ	Δ 1/κ	Δ²/ΔH²	Δx	Δ²H	Δ²x/ΔH²
1	3·9		587	1879·1	7390	151·1	0·006623					
2	5·7	1·9	735	1621·3	9240	128·9	0·007758	0·001135	0·0005970			
3	10·3	4·6	918	1121·14	11,550	89·1	0·011220	0·003462	0·0007526			
4	17·7	7·4	1083	770·2	13,630	61·2	0·016334	0·005112	0·0006907			
5	22·2	4·5	1167	650·9	14,450	51·7	0·019334	0·003000	0·0006666			
6	30·2	8·0	1197	500·	15,100	39·7	0·025219	0·005885	0·0007356			
7	40	9·8	1226	386·4	15,460	30·7	0·032557	0·007338	0·0007488	86·1	0·0237147	0·0007138
8	78	38	1337	216·5	16,880	17·1	0·058548	0·025991	0·0006842			
9	115	37	1370	150·7	17,330	11·9	0·084103	0·025555	0·0006911			
10	145	30	1403	122·6	17,770	9·7	0·1031	0·018927	0·0006306	105	0·07053	0·0006718
11	208	63	1452	88·8	18,470	7·0	0·1429	0·0398	0·0006318			
12	293	85·	1474	64·2	18,820	5·0	0·200	0·0571	0·0006717	148	0·09869	0·0006658
13	362	79	1489	52·7	19,080	4·1	0·2439	0·04389	0·0005557			
14	427	65	1504	45·3	19,330	3·5	0·2857	0·04418	0·0006803			
15	465	38	1508	41·8	19,470	3·2	0·3125	0·0268	0·0007052	172	0·1125·	0·0006514
16	503	38	1510	38·7	19,480	3·0	0·3	0·0208	0·0005474			
17	557	54	1517	35·2	19,630	2·7	0·3701	0·0701	0·0006587	92	0·0579	0·0006293
18	585	28	1530	33·9	19,820	2·6	0·38446	0·01442	0·0005147	220	0·0721	0·0006601

Calibration of Kohlrausch Unifilar Wattmeter. 10th Sept. 91

It was found that the wire previously used was not capable of giving reliable torsion readings with any angle exceeding 4π. It was a copper wire .0076 diameter. see p. 146 of 0.0076. This was changed for a copper wire drawn carefully to 0.010 diam. and which offered about three times the torsion. The new wire however was found very unsatisfactory owing from residual torsion and small range. A bifilar suspension of two 0.010 wires about 0.2 apart was next tried. The objection to it was the limited range ($\frac{\pi}{2}$). It was finally decided to increase the range of the instrument to the required degree by using the original wire 0.0076 but with a new exterior coil composed of two turns of copper strip 0.015 thick and 1.25 wide.

Obs.	R. in ext.	R.D. in rec.	Current corrected	P.D. obs.	R. obs.	Current obs.	C^2	τ	Coil	Value of $\frac{m}{H}$ deg. of τ	Ratio of times
1	3500	12.4	0.03513	1.100	31.17	0.03528	12.4147×10^{-4}	$7° 6' = 426'$ 4.930×10^{-3}	#1 2 turns	1.878×10^{-4}	55.27
2	3510	"	0.03532	1.098	"	0.03522	12.4014×10^{-4}	2.8°	#2 16	4.429×10^{-4}	13.77
3	3540	"	0.03503	1.082	"	0.03471	12.048×10^{-4}	$1.44.75'$	#3 96	8.324×10^{-4}	2.588
4	3535	"	0.03508	1.082	"	0.03471	12.048×10^{-4}	374.5'	#4 230	3.217×10^{-4}	1

In this test the current passed in series through both coils.

No. of Obs.	R. of volt	Volts P.D. as observed	Current in ampere unit calc.	Obsvd.	ampere in	Coil	Bc.	τ	Bc/τ	Means
1	1010	51.05	0.04989	0.266	1.373	#1	0.0674	124.7'	4.5485×10^{-4}	
2	has not at	51.50	0.04952	0.345	1.780	"	0.08815	190.5	4.628×10^{-4}	4.608×10^{-4}
3	Lamp 1014	51.80	0.04981	0.240	1.238	"	0.06167	134	4.6028×10^{-4}	
4		34.50	0.03317	0.083	0.4232	#2	0.02440	262.3	5.351×10^{-4}	5.396×10^{-4}
5		27.35	0.02630	0.131	0.6758	"	0.01778	326.9	5.440×10^{-4}	

Trenton Feeder Exhibit.

The length of the lamp board is 15 feet. It holds 15 lamps which will be fixed about 9 inches apart. The drop on a line 45' in length will be 2.5 volts or 1.25 volts on each wire. The lamps take as a mean p.d. of 101 volts and 0.647 γ each at 16 cp so that $3.75' + \omega = 1.25/16$ or $r = \frac{1.875}{3.75} = 0.5\omega$ per foot. ∴ 67.3 Watts for each lamp = 24.2 watts per cp.

The length of feeder (one way) is 60 feet = 120 feet of wire. The drop needed is 11.5 volts on 6.67 γ = 1.725 ω for 120'. ∴ 0.01438 ω per foot, the nearest size is # 22 B.W.G. 0.025" = 0.01317 ω per foot = 131 feet. say 130

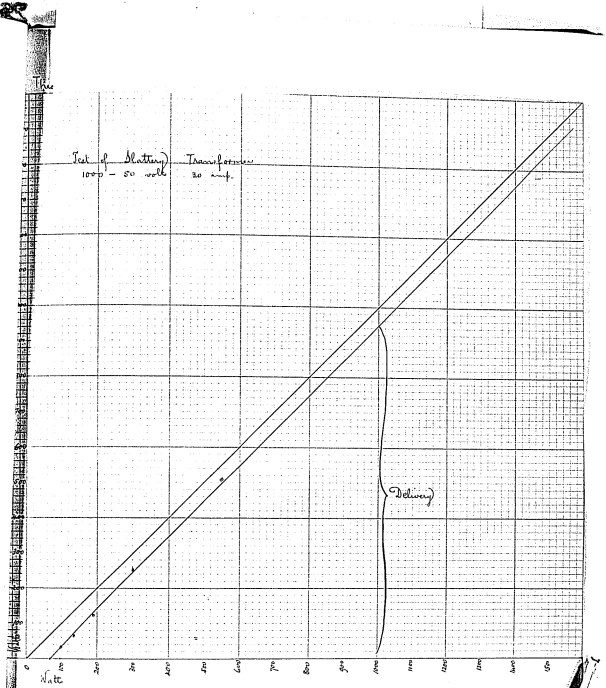
The length of feeder #2 (one way) is 100 feet = 200 feet of wire. The drop needed is 11.5 volts on 3.33 γ = 3.45 ω for 200' = 0.01725 ω per foot.

Artificial feeder made up with a 1000 watt regulating box and loops of #18 B.W.G. g.s.c.c. wire 53.25 feet 4.17 ω in 4+1 blocks of 0.1 ω each.

115.5	volts	at dynamo
11.5	drop in	feeder
104.0		at junction
2.9	drop in	mains
101.1		at lamps

10%
2.5%

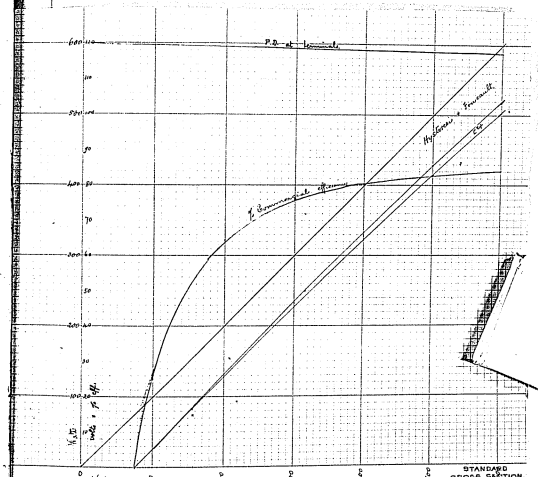
Res: of Feeder B 4.07 ω of #22 B.W.G. 0.029"
Res: of Feeder A 1.78 ω " "


Test of Shutting Transformer
1000 – 50 volt 20 amp.
Delivery
Watt

Efficiency Test of a Slattery Transformer (20 kw)

This transformer was operated at 10000 volts on the primary and working through a T. H. Wattmeter on 60 volt lamps.

No.	R	r	d	Primary Activity	Secondary volts	Load	Branch	amps	Secondary activity	Wattmeter reads	Wattmeter activity	
	17650	67	5.4×10^{-5}	63.9	52.5	0		0.633 per cent		0		
	18300	99.5		98.3	"	1 λ	0.125		33	"		
	19,100	140.5		137.3	52.6	2 λ	0.250		66	0.632	50 63	
	18,200	132.5		191.2	"	4 λ	0.488		132	1.715	125	
	18,150	22	4.605×10^{-6}	153.9	"	4 λ	"		132			
	17,600	37		300	52.5	8 λ	0.955		264	3.75	260	
	18,150	66		551.7	52.	16 λ	"		522	7.75	512	
	18,400	121.5		1029.	51.	32 λ			1044	15.5	1000	
	17800	161.25		1347.	50.	46 λ	5.			21.0	1320	


P.D. at terminals
Watts
STANDARD
CROSS SECTION.
10/32 N°.00.

Tests of Edison 500 Watt 10 Lamp Transformer

The design of this is represented on page 70. It was found necessary however to increase the depth of groove from 1.625" (4.125) to 1.7" ( ) in order to make room for the coils. The weight of iron in both secondary coil 2·8 lbs. The primary coil 2·87 lbs. The lbs. of primary coil 14·426 @ 20°C.
" secondary " 0·838 " "

and lid is 36 ½ lbs. The clamps 3 lbs. Total weight without shell 45 lbs.

Operated at 116 volts on each side of the secondary the following drop were observed :-

Lamps A side	Lamps B side	Total secondary current	P.D. at set	Means drop	Total P.D.	Mean Total drop	%	Eff. R. drop	Eff. Total drop
0	0		116			Secs. Pc		Secs. Pc	
1 λ	1 λ	0·424	115·7	0·3	231·2	0·6	0·26	0·4 0·4	
2 λ	2	0·98	115·4	0·6	230·5	1·2	0·52	0·7 0·8	
3	3	1·32	115	1·2	229·6	2·4	1·04	1·1 1·8	0·15
4	4	1·76	114·7	1·6	229·8	3·2	1·4	1·5 1·5	0·2
5	5	2·20	114·4	1·9	228·2	3·8	1·64	1·8 1·9	0·1
6	6	2·64	113·8	2·2	227·6	4·4	1·90	2·2 2·3	
7	7	3·08	113·4	2·6	226·8	5·2	2·24	2·5 3·5	0·1
8	8	3·52	113·	3·0	226	6·0	2·59	2·9 3·7	0
9	9	3·96	112·7	3·3	225·4	6·6	2·85	3·3 3·6	
10	10	4·40	112·4	3·6	224·8	7·2	3·10	3·7 3·6	

Measured the efficiency of the transformer as follows:-

R	T	RT	a	Primary Watts	Lamps	Shunts	Amps	P.D.	R	T	RT	Secondary Watts	Efficiency	Loss
18,120	79°	1.4318	5·345	76·5	0	0	0	119						76·5
18,120	162·5	2·944	"	157·4	1			119	1·			83·5		74
18,150	213·5	3·875	"	207·1	1+1				17,780	152·5	2·712	133·5	0·700	53·5
18,180	324·	5·891	"	314·9	2+2			117	17,890	244·3	4·373	248·6	0·742	66·3
18,090	36·5	6·604	4·572	321·9	2+2			117·5	18,230	25·5	4·675	248·6	0·705	73·2
18,670	60	11·09	"	542·3	4+4			116	17,720	48·	8·504	431·	0·766	107
18,270	69·5	12·715	"	609·8	5+5			115	17,980	57·	10·25	504·4	0·819	105·3

Div. secondary load 117

Calibration of Dynamometer for Alternating Current with Unifilar suspension + torsion.

Resistance of suspended coil 80 ω @ 20°C. The resistance of the anti-inductive boxes in circuit 17.500 ω. This circuit was joined up across the mains and currents measured by the Ohmeter, passed through the outer coils.

No of Obs.	Deflection mains	Reading deflected coil	τ	λ	Ohmeter	amps in outer coil	Coil #	Current in coil #	Cc.	α	
1	124	17.580	7°	1	0.101	0.521	1	0.007054	0.003676	5.251×10⁻³	5.251
2			14.5°	2	0.201	1.037	-		0.007314	5.016	10.090
3			20.2°	3	0.272	1.404	-		0.007002	4.456	10.368
4			43°	5	0.588	3.035	-		0.02144	4.978	15.346 / 15.339 / 1.472
5			191.5°	3	0.280	1.445	2		0.01019	5.32280	15.966
6			138.5°	2	0.206	1.063	-		0.007497	5.43	10.826
7			71°	1	0.103	0.531	-		0.003745	5.276	5.276 / 10.552 / 5.276

Experiment made to ascertain the danger of burning the hands of an electrocuted criminal if immersed in jars of water connected with the pole of the dynamo

15th Sept: 91.

A piece of raw beef about 2½" long and having a cross-section of about 3 sq: in: was layed across the edge of two glass gallon jars with one end dipping to the bottom of each. The jars were nearly filled with a solution of common salt in water of density 1. The resistance of the circuit formed of zinc electrodes, salt water, and beef was 530 ohms before turning on the current. The temperature of the water in the jars was 68°F (20°C). At 17.30.30, the alternating current of 780 volts. p.d. was turned on, generating a current by dynamometer of 5.01 A. It was maintained for 15 seconds on the first time and three after a pause for 30 seconds continuously. At the end of the second interval, the meat was on fire at one spot between the jars and gave a smell of roast beef. The temperature of the waters in the jars was not appreciably changed. The beef was not scarred or altered in appearance over the part that had been immersed in water.

If w be the apparent weight in grammes
$\mathfrak{M}$ " " " of zinc
c " " Expansion per unit volume for 1°C. of zinc
θ " " difference of temp. from standard.

$\frac{w}{\mathfrak{M}}$ = bulk of solution displaced

$1{\cdot}110\,\frac{w}{\mathfrak{M}}$ = mass of solution displaced

$\frac{1{\cdot}110\,w}{\mathfrak{M}} \times 0{\cdot}000758\theta$ = change in mass (Variance of weight with variance of temp.)

$\frac{8{\cdot}325}{\mathfrak{M}} \times 10^{-6}\theta$ gms = $1{\cdot}388 \times 10^{-3}\theta$ centigrammes

Correction is $0{\cdot}013\,88\ w\theta$ centigrammes

So that for 75 gms and 10°C - 10 centigrammes approximately

(89)

Tests of New Electrolytic Meter Sept. 16th 91 –

The following are observations made on the apparent weights and resistance after setting the meter up on the 16th Sept.

No. of Obs.	Date	Time elapsed	Weight of #1	Weight of #2	Res. of #1	Res. of #2	Temp.			
1	IX 17. 12.0		75·79	78·67	0·14	0·16	22°C.			
	17.0		75·32	78·71	"					
	18. 8.0		75·36	78·22	0·14	0·20	23.2°C.			
	IX 2. 8.30		88·53	85·43						
	IX 4. 17.15		88·27	85·81	Standish	lost	on 10 amps.	0·59	0·2 + 0·22 = 0·42	
	7. 22.00		87·76	85·59	Stopped		Loss of #1	Loss of #2	Probable Error	Mean
	8. 8.00		87·76	85·59	Started					
	8. 16.5		87·27	85·20						
	8. 22.30		86·89	84·90	Stopped		0·87	0·69	last 0·81	0·78
	9. 9.0		86·89	84·90	Started					
	9. 23.0 / 10. 8.0	9h.	86·10	83·97	Stopped		0·79	1·03	1·66	1·72
	" 13.0 / 12. 8.0	5h.	85·76	83·63			0·35	0·24	2·01	1·96
	" 12.0	4h.	86·00	83·73	no weights 4 days		+ 0·25	+ 0·10		
	15. 5.0		84·56	82·26			-1·99	-1·47	3·25	3·33
	19. 10.55		82·63	80·29	21°C. Coil off		1·89	1·97	5·14	5·30
	10.35		82·63	80·28						
	12.05		82·59	80·27						
	14.05		82·70	80·29						
	20. 12.5		82·77	80·42						
	21. 10.25		82·65	80·47	17°C.					
	22. 11.5		82·75	80·43	18°C.					
	23. 11.0		82·97	80·50	15°C					

Calibration of Obach, Standard, & Einheit Galvanometer 17th Sept. 91.

Copper voltameter 2·6 amp. about 60 sq: cms. of active surface.

a.R. Ohm

Set No.	Weights before test	Weights after test	Gain	Loss	Accepted Deposit	Duration of test	No: of dc	Mean Temp	Constants
	gms	gms	gms	gms	gms	secs			
1	33·8736 41·2110	33·1022 41·9854	0·7744	0·7714	0·7729	900	·57	0·5098	0·1951
2	29·8214 34·9970	28·3165 33·5062	0·5092	0·5080	0·5086	597	76	0·5805	0·1930
								Mean	0·19405

The Einheit and Fine wire coil of the Standard Galvo: were connected through potentiometer with a battery, and resistance.

Set No.	R. in Unity	P.D. in ms.	Millivoltmeter in ms.	Einheit	Ratio of Einh. to Millv.		Standard Tangent corr. Def.	Tangent	Tan. per m. amp.	Accepted value	Resist. for 1 m.
1	500	0·500	1	1·02	1·02		5°·30′	0·09629	0·09629		
	300	0·300									
2	800	0·980	2·875	2·89	1·0044		13°·10′	0·23393	0·09440		
	300	0·746	2·887								
3	300	1·422	4·74	5·3	1·119		24°·0′	0·44523	0·09392		
4	300	1·1414	4·811	5·4	1·122		24°·10′	0·44872	0·09328		
5	300	0·752	2·507	2·60	1·037		13°·10′	0·23393	0·09328		
6	300	0·510	1·70	1·76	1·035		8°·55′	0·15689	0·09228		
7	1000	0·522	0·522	0·55	1·053		2°·45′	0·04803	0·09201	0·09365	10·7×10⁻³
8	4000	0·794	0·4985	0·21	1·058		1°·0′	0·01746	0·08794		
9											

The Einheit thus overindicates in ratio 1·044 or 4% up to 3 ms. over that in overindicates about 11%

Table of Currents on Standard B.A.Galvo: for every 5° deflection

Set No.	Deflection	Tan.	Millivoltmeter				Deflection	Tan.	Millivoltmeter			
	5°	0·087749	0·936				50°	1·19175	12·750			
	10°	0·17633	1·887				55°	1·42815	15·28			
	15°	0·26795	2·866				60°	1·73205	18·53			
	20°	0·363397	3·894				65°	2·14451	22·95			
	25°	0·46631	4·989				70°	2·90421	29·40			
	30°	0·57735	6·177				75°	3·73205	39·93			
	35		7·492									
	40°	0·70021	8·972				80°	5·67128	60·68			
	45°	1·	10·700				85°	11·430	122·3			
							90°					

Test of Edison (1) 2 KWT alternating Current Transformer 1st trial. 17th Sept 91.

Weight without clamps iron and copper 123 lbs.
" of primary coil 24 lbs
" " secondary " 19.

The design of this transformer is given on p. 68.

When producing an effective p.d. on secondary open ckt: of 120 volts, the Reading on the primary showed 94 volts with 4000~ in ckt equivalent to $(94 + 8\cdot6) \times 9\cdot612 = 989$ volts

Two turns off each side should come from the secondary to reduce its pressure.

The torsion head of the dynamometer in the primary circuit indicated 115° with the current in primary + coil #2 and secondaries open 17680 in fine wire ckt. = $17680 \times 115 \times 5\cdot345 = 108\cdot7$ Watts.

Made following series of measurements with different conditions of magnetic ckt.

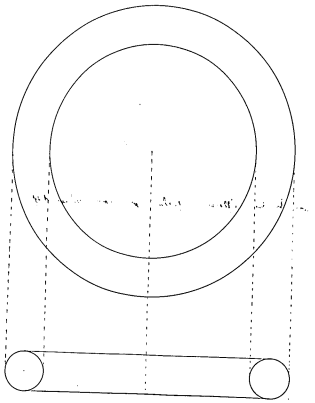
No of Obs.	Circuit	V	R.	α	Energy at sec Watts	Apparent on per ckt	Power	Amps: on pri. ckt	Load	Drop.	
1	As usual	115	17680	$5\cdot345 \times 10^{-4}$	108·7	0 mfd	0·0325	"		4 volts	
2		159	12,310	"	155·6	—				4 volts.	
3	Shunted 0·2 m	29	17,610	"	27·3	37°	1·4·157			4·7·	
4	Shunted 0·1 mm	105	17,630	"		0°				5·0	
5	Shunted 0·015 mm	110·5	17,930	"		—				5·0	
6	2 Second mm	−21·5	17,930	"		285				4·0	

Data of 2 an KWT transformer earth.

The secondary coil was divided into two equal parts, and the primary coil inserted between them thus + (diagram), about 1/16" placed out of base.

Weight of box	51 lbs.
" lid	29 ·
" primary	24 ·
" secondary	9 · 11 3
" "	9 · 11 3
Clamps	7 · 2
	130 · 8

Plan and Diametral Section of Nonmagnetic Iron Welded Ring. Scale 1/2.



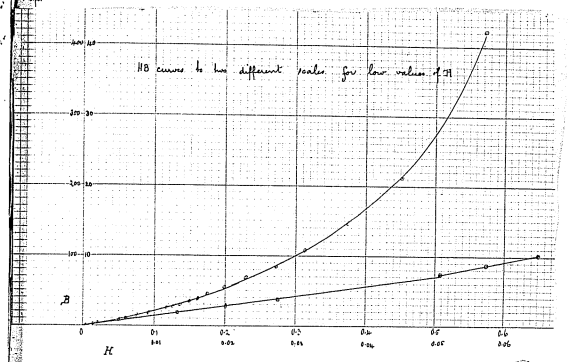
$5.305 \times 10^{10} \times 5.933 \times 10^{-10} = 47.80$
$1.5305 \times 10^{10} \times 2.9334 = 44.908$
$3.2446 \times 10^{8} \times 4.9334 = 1601.$
$1.05305 \times 10^{10} \times = 7601.$
$3.21305 \times 10^{8} \times = 1.5214$

External diameter	20.765	Circumference	65.235	Radius 10.3825 B.
Internal -	15.215	-	47.80	- 7.6075
Mean -	17.990	-	56.518	- 8.995 A

Difft diam ± plane of axis (mean of 4)	2.818
Radius mean - in - - - (- - -)	2.775
Cross section elliptical	6.[illegible] sq. cms.
Volume by dimensions	347.05 c. c.
Weight in air	2772.4 gms
- - by H_2O @ 19°C	2417.1
Loss of - - - - -	355.3
Specific gravity by weighings	7.802
Cross section by weight + sp.	6.286
Mean and accepted cross section	6.21[illegible]

Winding: 2 secondaries 250 turns each
Primary 320 turns in one layer

$$H = \frac{1.2566 \times 320 \times \text{amp.}}{56.518} = 7.114 \text{ amp.}$$



Measurement of Magnetic Reluctance in Norway Iron for very small values of Magnetic Force.

The forged ring of Norway iron whose test and dimensions are recorded on page 61 Book II ~~and stripped off~~ was stripped and annealed after fresh measurements had been made.

No. of Obs.	Source of EMF	EMF at temp.	Capacity	q_1	Mean throw	q_1 from dis.
117	1 B.C. at 22.8°C.	1.1293×10^{6}	1×10^{-9}	1.1293×10^{-7}	160.0	8.933×10^{-14}

No. of Obs.	Deflection	Stds. Tan	Amps.	Accepted	H	No. of throws	Mean throw	Ammr.	Commutat.	Ampl. at	Φ	ϕ	ρ 10^{-3}
1	1.18×10^{-2}	1	1.103×10^{-2}	1.103×10^{-2}	7.0166×10^{3}	1	1?	500	0	5.305	4739	0.763	10.285
1	1.65 "		1.402	$1.402 \times$	9.974 "	2	2?	"	"	"	9.478	1.525	6.524 "
2	2.08 "		1.916	1.916 "	1.363×10^{-2}	3	2.5	"	"	"	11.85	1.907	7.1646 "
3	3.08 "		2.851	2.851 "	2.028 "	6	3.62	"	"	"	17.16	2.761	7.346 "
4	4.1 "		3.833	3.833 "	2.727 "	8	4.94	"	"	"	23.41	3.767	7.24 "
5	5.05 "		5.15	5.15 "	5.087 "	7	9.76	"	"	"	46.26	7.444	6.832 "
6	6.05 "		6.056	6.056 "	5.753 "	7	11.6	"	"	"	54.97	8.846	6.502 "
7	7.05 "	0.86674	7.224 7.274	9.147 "	6.508 "	7	13.24	"	"	"	62.75	10.1	6.2422 "
8	1.10×10^{-2}	1.0898	1.078	1.052×10^{-2}	7.498 "	7	16.9	"	"	"	80.1	12.89	5.817 "
1	1.35 "	1.2349	1.343 1.263	1.2928 "	9.191 "	7	22.1	"	"	"	104.75	16.86	5.4852 "
2	1.72 "	1.5697	1.686 1.607	1.622 "	11.70 "	7	32.2	"	"	"	152.6	24.56	4.763 "
2	1.85 "	1.6977	1.773 1.729	1.773 "	12.615 "	7	34.8	"	"	"	164.9	26.53	4.758 "
3	2.0 "	1.8253	1.870 1.953	1.912 "	13.61 "	7	39.0	"	"	"	184.8	29.73	4.579 "
4	2.2 "	1.9868	2.056 2.126	2.091 "	14.89 "	7	44.35	"	"	"	210.2	33.82	4.398 "
5	2.39 "	2.1445	2.234 2.295	2.265 "	16.12 "	7	51.0	"	"	"	241.7	38.89	4.145 "
6	2.60 "	2.3597	2.420 2.523	2.478 "	17.63 "	7	59.1	"	"	"	280.1	45.07	3.911 "
7	2.95 "	0.03957	2.757 3.091	2.80 "	19.92 "	7	71.6	"	"	"	339.3	54.59	3.6149 "
8	3.40 "	0.04279	3.178 3.317	3.224 "	22.94 "	7	87.9	"	"	"	416.6	67.04	3.422 "
1	4.0 "	0.04570	3.734 3.843	3.84 "	27.32 "	7	109.1	"	"	"	517.0	83.21	3.284 "
2	4.6 "	0.05824	4.299 4.344	4.407 "	31.36 "	7	71.0	2.50	"	"	673	108.3	2.896 "
3	5.5 "	0.06116	5.141 4.742	5.25 "	37.36 "	7	95.8	"	"	"	908.	146.1	2.557 "
22	6.8 "	0.08163	6.357 6.329	6.334 "	45.11 "	7	138.9	"	"	"	1317.	211.9	2.129 "
23	8.5 "	0.10510	7.946 8.046	8.014 "	57.20 "	7	95.5	"	10,000	15,305	2620.	421.6	1.357 "
24	1.2×10^{-1}	0.15200	11.315 1.205	$1.163 \times$	82.74 "	7	198	"	25,000	38305	10720	1725.	0.14796 "
25	1.89 "	0.24162	1.7665 1.873	1.82 "	129.5 "	7	120.4	"	100,000	153,305	22,660	3647.	0.3350 "
26	4.60 "	0.56693	4.249 4.398	4.347 "	309.3 "	7	132.8	"	200,000	205,305	48.710	7838.	0.3245 "

II. Same lighting over the Tree system 2-wire.

Let w be the weight of copper in lbs: per foot needed to supply the most distant house with 1.5 volts total drop.

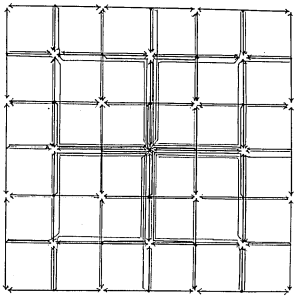
Then the total length of + conductor on any block facing is 4200 w.
The weight of + conductor on all block facings is thus 4 × 36 × 4200 w = 604,800 w.
Taking one 8th of the whole area in the triangle OAB

16 w are carried	2500 feet	=	40,000 w
3×16 w . .	2000 .	=	96,000 w
5×16 w . .	1500 .	=	120,000 w
3×16 w . .	1000 .	=	48,000 w
3×16 w . .	500 .	=	24,000 w.
	Total		328,000 w.

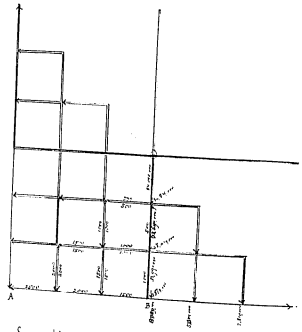
8 × 328,000 w = 2,624,000 w
Facing 604,800
3,228,800 w on + conductor
6,457,600 w on system.

The most distant house is 3000 feet and takes 7.5 amp. The drop being 1.5 volts on one conductor = 3000 × 7.5/1.5 = 15,000 ft. . $165 = 16,500
in units = 0.4975 lb.
Total weight of copper = 3,213,000 lbs. = $803,250 @ $0.25 per lb.
The main conductor leaving the station would be three in four pairs
Each taking 165,000 × $6.20 = $89,090,000 c. mils. feet.
Each pair . 2× . . = 178,180,000 c. mils

Diagram representing a city area fed from the centre on the 2-wire system with feeders.



Black lines mains
Red . feeders. Scale ¼ inch = 750'



Same plan arranged for a tree system of distribution.

TO DETERMINE THE COST OF COPPER NEEDED TO SUPPLY A CERTAIN AREA OF CITY WITH ELECTRIC LIGHT WITH THE EDISON THREE-WIRE SYSTEM, AND WITH THE MULTIPHASE ALTERNATING CURRENT SYSTEM.

Suppose it desired to supply a city area 4000 feet square, or a central block one mile of a square mile, and similar territory into seven blocks whose centers are 800 feet apart in directions of thereof lines. The streets are 100 feet wide, leaving 600 feet to each block facing. Suppose there are taken to each block facing a frontage of 20 feet each, and 15 lamps to each house all operated at 220 volts. There will then be 140 lamps on each block facing, a total of 36,000 to be supplied from the central station near the middle of the district. The station is located as at A. In the center of the area. The lamps are of 16 candle power each at 110 volts, taking 0.5 ampere at 110 volts pressure.

The conditions of supply are that all the lamps are to receive their pressure not to exceed 121.5 volts at the lamp posts, nor fall below 118.5 volts at the most distant points. The fall of pressure in the feeder wires is neglected. The fall of pressure in the feeders is to be one to the mile, or 5 volts in the 5 miles. The fall of pressure in the distributing mains is 1.5 volts.

The three wire distribution is considered. The copper conductors are calculated for 0.65 lb. per ampere per mile. The three wires are taken with lamps in a circuit of each wire. The wires may be all connected at generator or they may be disconnected at the center where the current varies at full load.

There will be a center of distribution at each block facing each conductor having a cross section of 250,000 circ. mils.

There will be four feeders of 600 feet each. The size of conductor being 800,000 circ. mils.

There will be four feeders of 1200 feet having conductors of 2,112,000 circ. mils cross section.

There will be twelve feeders of 1800 feet having conductors of 1,210,000 circ. mils.

Circuit	No. of lamps	Amperes per lamp	Amperes per circuit	Feet to center of distribution	Feet to center of feeder	Feet to station	Total feet	Circular mils of conductor
A	140	0.5	70	0.1	600	0.1	600	147,000
B	140	0.5	70	0.1	1200	0.1	1200	147,000
C	140	0.5	70	0.1	1800	0.1	1800	147,000
D	140	0.5	70	0.1	2400	0.1	2400	147,000
E	140	0.5	70	0.1	3000	0.1	3000	147,000
F	140	0.5	70	0.1	3600	0.1	3600	147,000
G	140	0.5	70	0.1	4200	0.1	4200	147,000
H	140	0.5	70	0.1	4800	0.1	4800	147,000
I	140	0.5	70	0.1	5400	0.1	5400	147,000
K	140	0.5	70	0.1	6000	0.1	6000	147,000
L	140	0.5	70	0.1	6600	0.1	6600	147,000
M	140	0.5	70	0.1	7200	0.1	7200	147,000
Totals							57,600 feet.	1,764,000

The total cost of copper is then 1,764,000 lbs. copper at 18¢, or is in all

THE EDISON THREE-WIRE SYSTEM.

The wire distribution over same area as same lamps.

The conductors of copper are laid all the lamps being operated at once. The conductors all uniformly vapor in cross section from the central station down to the most distant lamps.

The drop of the most distant lamps to be 3 volts, with a pressure of 118.5 volts, the station pressure being 121.5.

The cross section of main conductor at any point is directly proportional to the current carried.

There will be four pairs of conductors leaving from the central station, each conductor having a cross-section of 882,000 circular mils. There will vapor in accordance with the law of the current which may not exceed in a cross section of 147,000 circular mils at the most distant lamps. The total length of conductor will be 115,000 feet. The total weight of conductor 1,411,000 lbs. costing $ 254,000

The wires are disconnected at the center, that with at the station the termination of branches.

Determination of the Cost of Copper in a given system of arbitrary and uniform distribution of electric light (with the feeder system (a) with Tree system.

city) area 3000 feet square = 9,000,000 sq. feet = about 1/3 sq. mile
at central station at the center. Blocks are 1200 feet square, streets
00 feet wide, blocks centers uniformly distributed 500 feet apart in direction
thoroughfares. Sixteen (16) houses to each block facing, each houses having
5 lamps of 16 c.p. so that there are 2400 lamps to each block facing
960 lamps to each block and 34,560 lamps to be supplied in all.
The lamps to be ½ amp. 100 volt 50 watts 16 n.c.p. with negligible drop in house
wiring and the pressure is never to be less than 98.5 or more than 101.5
any lamp. Required the distribution necessary at full load.

1st Feeder system. 2 wires

Assume 24 feeders, one feeder to each 8 block facings or eventually one
large system, one to each block. Each length of main is 500 feet.
and each has 2400 lamps whose dist. cent. is 300 feet distant from the
junction box. Allow 1.5 volts drop for 120 amps carried 300 feet on one main +
and 1.5 volts on return main (−) . $120 \times 300 = 36000 \div 1.5 = 24{,}000$ K= 2616,000 cm
This is the size of each mains. The total copper in each main is thus
$2616{,}000 \times 500 = 132$ million cmft. = 400 lbs. The weight of copper to each
block facing will be (2 mains) 800 lbs. or 3.3 lbs. of copper per lamp. There
are 1440 block facings or 115,200 lbs. of copper @ 25¢ = $28,800 worth of copper
in the mains.

If the feeders there are 3 types

of Type I. Length 500 feet carries 8 block facings. or 1920 lamps = 960 amp.
8 " II " 1500 " " " " " "
12 " III " 2500 " " 4 " 960 1680 "

Allow 1½ volts drop in each feeder. Then 7.5 volts drop on each side of
it. $\frac{500 \times 960}{7.5} = 64{,}000$ K = 704,000 c.mil. and 500 feet = 352 million
c.mil. feet in each conductor = 704 million c.m.ft in each feeder or 2816 m.c.m.ft
in all four feeders = 8490 lbs. = $2,123 or $0.276 per lamp supplied

II. $\frac{1500 \times 960}{7.5} = 192{,}000$ K = 2,112,000 c.mils. and 1500 feet = 3168 million
c.mil feet in each conductor = 6336 mil. c.m.ft. in each feeder or 50688 m.c.m.ft
in all 8 feeders = 152,900 lbs. = $38,225 or $2.49 per lamp supplied

III. $\frac{2500 \times 1680}{7.5} = 160{,}000$ K = 1760,000 c.mil. and 2500 feet = 4400 m.c.m.ft.
in each conductor = 95600 m.c.m.ft. in each feeder or 105600 m.c.m.ft in
all 12 conductors feeders = $38,350 lbs. = $1[illegible] or $6.908 per each lamp
supplied

Tabulating all the copper

Conductor	Number	Drop in	Size	Weight per foot	Total Weight of conductor per foot	Total weight of conductor	Total cost of conductor	Cost of 1 lb. of copper in conductor	No. of lamps supplied	Cost of conductor per lamp	Length of each conductor	Total length of conductor	Total length of feeder
		volts	c.m.	lbs.	lbs.	lbs.	$	$		$	ft	ft	ft
Main	288	1.5 o.	264,000	0.8 lb.	1.6	800	$200	25,800	34,560	$0.833	500	144000	7,200
Feeder I	14	7.5	704,000	2.123	4.246	2,123	531	2,124	7,680	0.276	500	4,000	2,000
Feeder II	8	7.5	2,112,000	6.369	12.738	19,110	4,776	38,225	15,360	2.49	1500	24,000	12,000
Feeder III	12	7.5	1,760,000	5.306	10.612	26,530	6,633	79,590	11,520	6.908	2500	60,000	30,000
						48,563		148,739	34,560	4.302		282,000	51,200

Bottle heads
Φ
Current flow
Working flow and velocity
Theoretical velocity
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000
23000
24000
25000
26000
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85000
86000
87000
88000
89000
90000
91000
92000
93000
94000
95000
96000
97000
98000
99000
100000

Magnetic Test of pair 2 KWT. Transformer Sept: 21st 91.

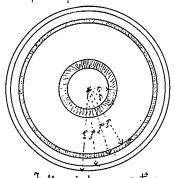
Five turns of wire were wrapped round the primary coil, and connected to the ballistic galvanometer.

Exp. No.	Source of EMF	EMF at temp	Capacity	Q.	Mean throw	q. per div.	R. of G.
6	1 Cell @ 22°C.	1.43302	1f	1.43302×10^{-6}	155·3	9.21×10^{-10}	52850

Exp. No.	Ballist. throw	Stat. q. throw	Amp:	Amplitude corrected	MMF.	No. of Turns	Mean throw	Reading on G. scale	R. of G. ckt.	Φ	$\mathfrak{R}$	ρ	No. of turns
											$\times 10^{-3}$		
1	0·03245	0·03987	0·03009	0·032	28·15	5	10.	0	5285	4870	57.8		5
	0·03790	0·04655	0·03612	0·037	32·55	5	12·36		"	6530	49.8		
	0·04455	0·05533	0·04290	0·043	37·83	5	13·9		"	7350	51.4		
	0·05140	0·06313	0·05127	0·051	44·86	5	17·5		"	9250	48.4		
	0·06850	0·07870	0·06102	0·061	53·66	5	20·36		"	10760	49.9		
2	0·08230	0·10216	0·07925	0·0795	69·92	5	27·91		"	14770	47.3		
	0·11105	0·13758	0·1067	0·1067	93·85	5	39·7		"	20980	44.7		
	0·17495	0·22469	0·1759	0·1759	154·7	5	95·0	50.000	"	50220	30.8		
	0·37795	0·46953	0·37955	0·37955	333·9	5	6944	50,000	5285	353500	9.9246		
0	0·47275	0·58709	0·46552	0·46552	409·4	5	96·3	"	"	49.0200	8.8164		

Data of Ferranti Underground Tubes.

Calculated and copied from the London "Electrician" May 15th 1891.



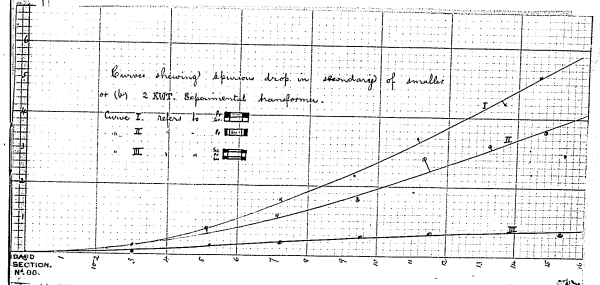
Full sized cross section

r_1 r_2	R_1 R_2	R_3 R_4	Area of inside wire	Area of inside copper	Area of insulator	Area of outside copper	Area of outside lead	Area of iron	Weight of copper	Weight of iron			
0·7162 1·031·2	2·3223 2·462	4(5·338) 4(5·713)	1·602	1·738	13·89	1·81	5·248	2·97	87.50 per mile	23·17 per mile			
0·281" 0·406"	0·922" 0·764"	1.40 1.663	0·2258 in	0·27 in	2·153 in	0·279 in	6·851	0·462	87.50 per mile	0·154 lbs per mile			
$\log_e \frac{R_2}{r_2}$	C	Capacity per mile of air ins.	Observed Cable per mile	Sp. G. of Iron	Inductance per mile	Ld per cent	Area of lead and copper sheathing	Insulation per mile					
0·8198	0·6097	0·109 f	0·361 f	3·367	0·2957 h	1·7755	0·3246	9202					

No of Test	Weight of Plate before test	Weight of pan before test	Weight of Plate after test	Weight of pan after test	Gain	Loss	Steam pressure	Complete gain	Motor Count.	Count per	Mete reduction	Mete hunting	Remarks
1	47.3685	46.1300	46.3152	46.1600		0.7615							
2	48.8030		46.9771		0.773		0.7673	0.0110		861.6	0.0065	1.000	
3	48.5220	42.4.05	46.5086	42.2096		1.0111							
4	46.8238		46.8011		1.0776		1.6608	0.0905	8714	877.2	0.0923		
5	46.5700		46.2809										
6	47.1925	41.3135	46.8859	41.3870		1.0665							
7	47.0917		46.8826				1.0843	0.0965		983.8	0.0183		
8	46.5889	42.4220	46.8581	42.3472		0.2030							
9	46.6050		46.4.571		0.2220		0.2128	0.020	4	852	0.010	0.9880	1.2 —
10	46.8293	42.3760	46.6.160	42.3.580		0.186							
11	47.0850		46.5.311		0.3.243		0.2092	0.0144	4	833.8	0.022	0.9868	3.3 —
12	46.8281	41.4.18	46.5.111	41.4.27		0.190							
13	47.077		46.9.1147				0.2110	0.0211	4	84.00	0.020	0.9850	2.5 —
14	47.1930	42.3925	46.7.1642	42.3.1925		0.230							
15	46.9235		46.7.1.02		0.2225		0.2.125	0.025	4	852.0	0.0125	0.9948	0.8 —
16	46.9055	41.4.88	46.8.1.02	41.4.96		0.2035							
17	46.6.125		46.8.865		0.3225		0.2130	0.0172	4	852.	0.0086	0.989	1.1 —
18	46.8.20	41.4.89	46.8.511	41.4.551	0.2625								
19	46.8.20		47.2.140			0.180	0.2113	0.062	4	846.2	0.031	0.981	1.9 —
20	47.3230	42.6.1055	47.2.2.55	42.6.401	0.0125								
21	47.0535		46.9.0645		0.0130			0.0225	4	—	0.0128	—	
22	46.8.20	43.6.1055	46.7.1.22	43.6.556		0.232							
23	46.8.20		46.8.1.95				0.2108	0.0205	4	84.3.2	0.0103	0.9788	2.1 —
24	46.1.65	47.0378	46.7.1.55	47.0.89		0.14.895							
25	46.9.15		46.9.1.2				0.4.390	0.0195	2	878.0	0.0093	1.019	1.9 +
26	47.1.720	44.3170	46.9.2.60	44.2.60			0.4.375						
27	46.8.060		50.0.60	44.3.20		0.1.2.55		0.4.415	0.029	2	883.0	0.0145	2.5
28	46.1.60	43.862	46.8.6.72	43.9.110		0.4.615							
29	47.6.850		47.2.53				0.432	0.4.468	0.0225	2	893.6	0.0112	1.027	2.7
30	47.1.720	45.355	47.2.03	45.360		0.427							
31	47.1.443		47.2.35		0.1.473		0.4.42	0.025	2	880.	0.0125	1.022	2.2
32	48.1.08	45.6.58	46.8.8.18	45.6.89		0.1.435							
33	47.252		46.5.285		0.1.33.5		0.4.206	0.022	2	869	0.011	1.009	1.9
34	46.8.20	47.191	46.8.021	47.2.20									
35	46.7.108		46.9.103		0.1.43		0.4.34	0.023	2	868	0.0115	1.008	0.8
36	46.9.15	46.009	46.7.1.60	46.0.60	0.1.45.5								
37	46.9.0.35		48.6.91.8		0.1.305		0.4.448	0.0.58	2	881.6	0.0.29	1.023	2.3
38	47.1.20	49.600	47.1.2.50	49.6.60		0.1.110							
39	47.1.20	49.600	47.1.2.50	49.6.60	0.	0.1.20	0.4.398	0.0145	2	879.6	0.0.29	1.021	2.1
40	47.1.20	49.600	47.1.2.50	49.6.60	0. 1.44								
41	46.8.30	47.011	47.1.2.86	47.0.32	0. 1.2.5.6	0. 1.2.6	0.4.360	0.0.24	2	872.0	0.0.05	1.012	1.2
42	48.1.60		47.1.1.56		0. 0.66								
43	47.1.71	48.810	46.8.6.23	48.0.30	0. 1.2.2		0.4.393	0.0235	2	878.6	0.0.18	1.020	2.0
44	47.1.78		47.2.2.18			0.1.266							
45	46.867	43.310	46.8.6.83	43.1.230	0. 1.2.18		0.882	0.0.30.5	1	882.	0.0173	1.024	2.4
46	47.2.20		48.8.6.65			0. 1.2.62							
47	47.1.80	45.558	46.8.6.48	45.3.28	0. 1.2.0.5		0.8781	0.0265	1	878.1	0.0133	1.020	2.0
48	46.1.03		47.1.2.30			0.8647							
49	47.1.307	46.756	46.8.6.08	46.4.76	0. 1.2.77		0.8865	0.0.19	1	886.5	0.0095	1.029	2.9
50	47.1.388		48.0.2.60		0. 1.2.96								
51	46.9.14	42.1.56	46.6.08.5	42.1.62		0. 1.2.54	0.8.574	0.0.27	1	867.2	0.0135	1.007	0.7
52	47.2.27		46.6.058		0. 1.2.81								
53	47.1.86.4	41.4.63	46.8.7.35	41.4.96	0. 1.2.91		0.876	0.0.29	1	876.0	0.0145	1.017	1.7
54	47.1.081		46.6.220			0. 1.2.61							
55	48.1.84	47.1.2.91	48.0.0.2.2	47.1.2.76	0. 0.20	0. 1.2.43	0.8.591	0.0.30	1	881.0	0.0.40	1.023	2.3
56	47.1.051		47.2.0.71										
57	46.9.06	43.3.52	46.8.7.37	43.3.82	0. 1.2.91		0.876	0.030	1	876.0	0.015	1.017	1.7
58	46.1.26.5		47.1.2.55			0. 1.2.61							
59	50.5.52	44.1.60	46.7.08	44.0.225		0. 1.2.44	0.874	0.040	1	874.	0.020	1.015	1.5
60	47.1.13		50.3.17		0. 1.2.0.4								
61	48.1.84.5	43.1.20	46.8.7.60	43.1.32.2	0. 1.2.79		0.8.738	0.0.108	1	875.2	0.0.53	1.014	1.4
62	48.1.07.7		46.7.1.80			0. 1.2.64							
63	46.1.03	42.3.08	46.4.07.6	42.1.60.0	0. 1.2.12		0.857	0.8.8.2.5	0.0.56	1	88.6.5	0.028	1.027	2.7
64	47.1.18		46.8.0.27			0. 1.2.43							
65	48.1.62	47.1.7.15	46.1.2.72	47.1.7.89	0. 1.2.7		0.859	0.0.77	1	889.	0.039	1.032	3.2
66	46.2.6.8		46.8.0.47			0. 1.2.61							
67	46.7.0.31	45.3.13.5	46.7.0.6.2	45.3.46			0.8.8.3.5	0.8.8.0	0.0.32.5	1	880.	0.0163	1.022	2.2
68	47.3.8.25		46.5.27.0		0. 1.2.6.5								
69	48.9.0.8	46.2.00	46.9.2.6.0.3	46.2.52.9	0. 1.2.0.4		0.8.7.6.6	0.0.24	1	87.6.2	0.0.10.5	1.017	1.7
70	46.7.0.5		46.6.2.5.5			0. 1.2.6.2.5							
71	46.8.2.2.3	46.1.1.1	46.7.2.7.7	46.1.6.9	0. 1.2.4.2		0.8.7.6.5	0.0.28	1	87.6.5	0.0.14.0	1.020	2.0
72	47.0.1.9	45.2.6.7	46.8.0.8.1	45.2.6.5	0. 1.2.0.3.5								
73	46.7.2.6.6	45.2.6.7	46.5.0.7.5	45.2.6.5			0.8.5.5	0.8.6.5	1	87.9.3	0.0.2.4.3	1.021	2.1
74	46.8.2.2.3		46.7.2.7.8			0. 1.2.0.3.5							
75	46.7.0.3.0	43.8.5.2.4	46.6.0.7.1	43.8.2.7.3	0. 1.2.0.3.5		0.8.5.6	0.8.7.4.8	0.0.14.4	1	87.4.8	0.0.2.2.0	1.016	1.6
76	46.8.5.9.0		46.4.6.1.5			0. 1.2.0.3.5							
77	46.8.5.2.7	47.0.7.5.5	46.9.6.0.0.3	43.0.2.8.5	0. 1.2.0.3.5		0.8.6.0.5	0.0.48.5	1	89.0.5	0.0.2.4.3	1.024	3.2
78	46.8.6.2.5		46.8.6.1.5			0. 1.2.0.3.5							
79	46.1.40.2	46.7.0.9.4	47.0.2.8.0.3	46.7.0.3.5	0. 1.2.0.3.5		0.8.6.6.5	0.0.33.0	1	88.9.5	0.0.16.5	1.033	3.3
80	46.7.2.5.5.5		46.0.3.2.0.3			0. 1.2.0.3.5							
81	46.7.0.1.7	45.0.2.8.7	46.7.0.8.7	45.0.2.8.2	0. 1.2.0.3.5		0.8.7.1.5	0.8.6.2	1	89.2	0.0.2.5.5	1.026	2.5
82	46.7.2.3.5		46.6.4.7.7			0. 1.2.0.3.5							
83	46.8.5.7.0	45.0.6.5	46.8.0.1.7	45.0.4.0.0	0. 1.2.0.3.5		0.8.6.3	0.0.6.1	1	89.6.3	0.0.3.2	1.041	4.1
84	46.7.1.3.6	44.6.3.1	46.6.4.6.3	44.6.4.2.5	0. 1.2.0.3.5								
85	46.7.0.4.2.5		46.7.0.5.5			0. 1.2.0.3.5	0.1.7.5.5	0.2.6.9.0	0.0.6.4.5	10	83.2.0	0.0.2.3.3	0.9.6.7.5	

Meteorological Record

Date	Time	Barometer (13) Inches	Cm.	Temp.	Gravity to 0°C.	Thermometer. Max	Min	Dry	Wet	Rainfall in 24 hrs.	Wind	Remarks
1891												
Sept. 12						78°	48°	72°			S	
	13					73	57	67			NW	
	14					70	55	67			W	
	15					72	58	72			N	
	16					77	52	72			N	
	17					81	63	80			W	
	18					82	68	78			N	
	19					80	65	76			SE	
	20					79	62	77			E	
	21					77	60	80			NE	
	22					74	62	76		0.	SE	
	23					82	63	78		0.	SW	
	24					81	67	75		0.	W	Cloudy
	25					79	67	75		0.57	S	"
	26					78	67	78		0.	S	"
	27					78	53	62		0.12	NE	Clear
	28					78	45	63		0.	E	Fair
	29					68	46	58		0.	W	Cloudy
Oct.	1					74	48	68		0.	W	Fair
	2					80	55	76		0	NE	Cloudy
	3					79	57	60		0	N	"
	4					61	45	52		0.08	NE	Raining
	5					59	51	59		0.60	N	Cloudy
	6					59	43	54		0	NE	"
	7					62	42	54		0	NE	"
	8					60	36	46		0	NE	"
	9					64	41	47		0.23	NE	Raining
	10					57	43	51		0.02	SW	Fair
	11					60	43	55		0.0	SW	Cloudy
	12					57	35	50		0	NE	Fair
	13					56	38	46		0	NE	"
	14					56	40	54		0.55	SW	"
	15					55	44	50		0	W	"
	16					50	43	44		0.67 (3)	W	Raining
	17					45	34	42		0.53	N	Fair
	18					53	28	53		0	W	Fair
	19					53	44	50		0.20	NW	"
	20					45	32	40		0	N	"
	21					46	25	44		0	S	"
	22					54	34	54		0	SW	"
	23					54	35	54		0	W	"
Nov.	24					42	25	41		0	N	Clear
	25					42	28	38		0	N	"
	26					40	23	30		0	N	"
	27					41	26	41		0	NE	Drizzling
	28					54	34	54		0.02	NE	Clear
	29					57	33	57		0	N	Cloudy
	30					57	40	57		0.01	E	Foggy
	31					60	50	60		0.27	SW	Clearing
	1					60	30	60		0.03	"	Fair
	2					58	37	58		0	NW	Cloudy
	3					54	31	49		0.05	E	Raining
	4					52	28	47		0.42	SW	"
	5					42	22	37		0.52	W	Fair
	6					33	20	33		0	SW	Clear
	7					44	24	42		0	E	Fair
	8					46	28	46		0	E	Cloudy
	9					54	44	54		0.75	W	Raining
	10					57	39	50		0.08	W	Cloudy
	11						37	40		0	SW	"
	12						27	41		0.14	W	Fair
	13						18	32		0	NW	Clear
Dec.	14						20	32		0	SW	Clear
	15						27	34		0	SW	Fair
	16						32	50		0.04	SW	Cloudy
	17						35	54		0.64	SW	Rain
	18						32	42		0.64	SW	Raining
	19						29	36		0.01	"	Clear
	20						29	41		0		"
	21						28	46		0		Fair
	22						38	49		0		Clear
	23						31	41				


Curves shewing fall in voltage of small
(b) 2 KWT. Experimental transformer.
Curve I. refers to
" II " "
" III " "
I
II
III

Data and Tests of 2 KWT (b) Transformer.

Weight of Iron box 38 lbs.
" " lid 22.
" " clamps 6.- 8
" " Primary coil 13 - 9
" " 2ndary " 16 - 1
96 - 2

For design see p. 69.

Res: of primary coil 3.412 ω @ 20° C Inductance (28.9 ~ 2.85) = 72.28 h.
" " secondary " 0.223 ω
Mutual inductance superposed (28.9 ~ 2.18, 2.85, 2.93) = 9.26 h.

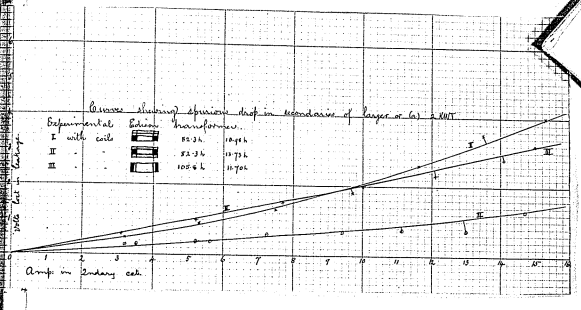
Mark	Primary C.	Load A amp	Load B amp	Dynamometer in B ✓	Amp in B	Volts in A	Drop in per.	Drop Equivalent in sec.	Observed drop in secondary	Sparnish drop
1	0.2	0	0	0		117.	0.68 v.	0.082		
2	0.44		5	6.5 2.55	2.333	116.7	1.36 v.	0.163	0.3	0.114
3	0.71		12	31 5.568	5.095	116.	2.143	0.29	1.0	0.71
4	0.98		17	61.5 7.842	7.176	115.	3.35	0.44	2.0	1.6
	1.25		22	104 10.2	9.333	114.2	4.27	0.5	2.8	2.3
	1.5		27	147.5 12.14	11.11	113.	5.12	0.61	4.0	3.39
	1.72		32	198.5 14.09	13.63	111.9	5.94	0.71	5.1	4.39
	1.9		37	253 15.91	14.56	111.	6.48	0.78	6.0	5.33

As a modification of this, a new pair of coils was wound, the primary outside, and the secondary within.

Res. of primary 3.803 ω @ 25°C. Inductance (27.472, 3.2, ~) = 87.9 h.
" secondary 0.181 ω " "
Mutual inductance (27.472 ω, ~, 2.85, 3.2, 3.75) = 9.52 h.

	Primary C.	Load A.	Load B.	Dynamometer in B ✓	Amp in B	Volts on A	Drop in per.	Drop Equivalent in sec.	Observed drop in secondary	Sparnish drop
	0.2	0	0	0		117	0.76 v.	0.09		
2	0.52		7	11 3.317	3.035	116.5	1.98 v.	0.24	0.5	0.26
3	0.73		12	31 5.568	5.095	115.9	2.77 v.	0.33	1.1	0.77
4	0.98		17	60 7.746	7.087	115.4	3.73 v.	0.45	1.6	1.15
5	1.29		22	105.5 10.28	9.404	114.8	4.91 v.	0.59	2.2	1.61
6	1.53		27	153 12.37	11.32	113.5	5.82 v.	0.70	3.5	2.8
7	1.78		32	208 14.42	13.19	113	6.77 v.	0.81	4	3.99
	1.9		37	262 16.19	14.81	112.5	7.23 v.	0.87	4.5	3.63

There is thus a very distinct advantage gained by placing the coils thus ▭▭ instead of ▭▭. The sparnish drop with the former arrangement is about 25% less than with the latter.


Curves showing spurious drop in secondaries of larger or (a) 1 KW Experimental Edison transformers.
I with coils 85-3 h. 10-4 h
II - - 82-3 h. 12-3 h
III - - 105-6 h. 11-7 oz
Amps in Secondary coil.

Tests of larger or (as) 2 KWT. Transformer. 29th Sept. 91.

The secondary coil of this transformer was divided into two halves Thus ⅛ and superposed upon the primary. The following readings were then taken:—

No of Obs.	Primary C.	Load A side	Load B. side	Dynamo in B.	✓	Amp in B 0.915	Volts on A	Drop in Primary	Equivalent drop in Secondary	Observed drop in Secondary	Dynamic drop
1	0.25	0	0	-							
2		20	20				109.9				
3	0.55	0	7	12°	3.4684	3.170	116.4	1.02	0.12	7.1 0.6	0.5
4	0.76	0	12	32.6	5.710	5.225	115.9	1.69	0.20	1.8	0.9
5	1.02	0	17	66.5	8.185	7.462	115.4	2.20	0.26	2.6	1.3
6	1.32	0	22	113.5	10.65	9.744	114.8	2.87	0.34	2.2	1.8
7	1.59	0	27	161.0	12.69	11.61	114.0	3.43	0.41	3.0	2.6
8	1.83	0	32	216.5	14.71	13.46	113.0	3.97	0.48	4.0	3.5
9	2.05	0	37	281.	16.76	15.34	112.5	4.53	0.54	4.5	4.0

The secondary coils were now divided, and the primary inserted between them — ⅛ ⅛ and the readings repeated as follow:—

No of Obs.	Primary C	Load A side	Load B. side	Dynamo in B	✓	Amp in B	Volts on A	Drop in Primary	Equivalent drop in 2ry	Observed drop in 2ndy	Dynamic drop
1	0.2	0	0								
2		20	20				111.5			4.0	
3	0.49	0	7	12°	3.4604	3.17	115.1	1.02	0.12	0.4	0.3
4	0.70	0	12	32°	5.657	5.176	114.9	1.67	0.20	0.6	0.4
5	0.97	0	17	62.8	7.925	7.252	114.6	2.14	0.26	0.9	0.6
6	1.27	0	22	106.5	10.32	9.442	114.5	2.79	0.34	1.0	0.66
7	1.49	0	27	148	12.17	11.14	114.4	3.29	0.39	1.1	0.7
8	1.74	0	32	201	14.18	12.97	114.3	4.18	0.50	1.2	0.7
9	2.0	0	37	259	16.09	14.72	113.6	4.75	0.57	1.9	1.3

Res: of primary 2.995 ω. Res: of each secondary coil 0.1005 ω. @ 20°C.

Inductance of primary 82.3 h. (26.73 100/n 3.08²)

Mutual Inductance of primary and two secondaries superposed as in sketch at top of page (26.73 100/n 2.65² - 3.07² - 3.48²) 0.415 × 26.73 /10 = 10.98 h.

Mutual Inductance when primary inserted between secondaries as in sketch at center of page (26.73 100/n 2.585² - 3.07² - 3.59²) 0.50 × 26.73/10 = 13.36

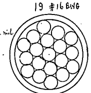
$$c = \frac{1}{2 \log_\varepsilon \frac{4h}{d}} \qquad \frac{c \times 10^{15}}{9 \times 10^{20}} \times 1.60933 \times 10^{5} = c \times 1.7881 \times 10^{-1}$$

$$= 0.1788\ c$$

Taking Capacity per mile of overhead wire as 0.03^{φ} and $r = 16.4$
ωq per mile = 0.492 say 0.5. ~~p~~
and $\Omega \varphi = \frac{l^2}{2}$

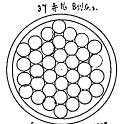
19 #16 BWG

Lead 1.4 lbs per foot 7392 lbs per mile
Copper 0.2432 - - - 1283 - - -



R_1 0.49" R_2 0.575"
0.065" 0.2844 sq in:

37 #16 B.W.G.s.



Lead 1.95 lbs p. ft 10,300 lbs p. mile
Copper 0.474 - - - 2,514 -

R_1 0.7" R_2 0.783"
0.085". 0.396 sq in:

Cablegram received by Mr Kruesi from Siemens & Halske Berlin:–

"The entire cable used by the Government has earth return. Charge depends upon ratio between diameter of copper and thickness of insulation. One mm: of copper and 2.8 of insulation is ~~0~~ 0.2 microfarad of insulation with T. C. Mass and Jute.

On the number of wires having equal diameters that naturally form a cable.

The law of formation is that in the Rth ring (omitting the center or calling it zero) the number of wires is 6 R so that the total number in a cable of R rings is $N = 1 + 3R(R+1)$ When R = 0 N = 1

R	N
0	1
1	7
2	19
3	37
4	61
5	91

$\log_\varepsilon 2.8 = 1.03 \times 2 = 2.06 \qquad 1/2.06 = 0.4854 \times 0.1788 = 0.087 \therefore K = \frac{0.2}{0.087} = 2.3$

Data for the dimensions of a R.R. Telegraph Cable from New York to Philadelphia, for the Penna. R.R.Co.

The length of the line may be assumed as 100 miles of 5280 feet. The cable to be lead covered and each wire to be insulated with jute soaked in insulating compound. The following are some data for overhead iron wires.

Size of wire	Diam.	Ohms per mile	Height above ground	$\frac{4h}{d}$	$\log \frac{4h}{d}$	$\log_\varepsilon \frac{4h}{d}$	Cap: per cm.	microfarads per mile	$\varphi \times \omega$
# 8 B.W.G.	0.165"	16.4 ω	5'	1454	3.16256	7.28	0.0687	0.01229^{φ}	0.2016
" " "			10'	2909	3.46374	7.975	0.0627	0.01121	0.1838
- - -			20'	5818	3.76477	8.668	0.05767	0.01031	0.1691
- - -			30'	8728	3.94091	9.074	0.05510	0.00985	0.1615

Seventeen circuits are needed by the R.R.Co., 10 to be way wires 7 to be through, and 2 of these latter worked quadruplex.

We will assume a thickness of insulation of 1/16" all round the wire and first consider the simple retardation of a wire, 100 miles long its dielectric constant 3.0, and each wire's external insulator surface grounded.

	Diam. of copper wire	Thickness of insulation	Diameter over all	$\log_e \frac{D}{d}$	c	capacity per mile air	Capacity per mile K = 3	Res. per mile	ω × φ for 100 miles	Equivalent length of overhead.
	0.065" #16 BWG.	0.0625"	0.190"	1.072	0.466	0.0833	0.250^{φ}	12.9 ω	32,250	254 miles

If owing to the fact that each wire is not sheathed and connected to ground, its capacity is halved, then 0.125^{φ} 12.9 ω 16,125 180 miles

A metallic circuit of the same wire would on the first supposition = 508.
- - - - - - - - - - second - = 360.

The weight of #16 BWG. per foot = 0.0128 lbs. or per mile 67.53 lbs.
19 wires of #16 BWG - - - = 0.2432 - - - - 1283 - = \$321 @ 0.25
19 wires - - - - for 100 miles = \$32,100.
38 - - - - - - - - - = \$64,200.

The wire being taken as #18 B.W.G. "

#18 BWG	0.049"	0.0625"	0.1740"	1.267	0.395	0.0707	0.212^{φ}	22.7 ω	48,100	310 miles
38.4 lbs per mile	allowing half capacity						0.106^{φ}	22.7 ω	24,050	220.
	With metallic circuit allowing half capacity.									440.
#20 BWG	0.035	0.0625"	0.160"	1.52	0.329	0.0588	0.176^{φ}	44.5 ω	78,300	396.
19.6 lbs per mile	Allowing half capacity									280.
	With metallic circuit allowing half capacity									560.

37 wires of #18 B.W.G. would weigh 1421 lbs per mile = 142,100 lbs total or \$35,400
- - - - 20 - - - 725 - - - = 72,500 - - - \$18,750
One #10 BWG wire would weigh 287 - - - = 28,700 - - - \$7,175

0.0254" / 0.1	0.0228" / 0.09	0.0710" / 0.28	1.0296	0.4857	0.08684	0.268^{φ}	4 per Kilometer = 0.166^{φ}

Let d = distance between cars or in section in feet

Then L = length of road in feet

L/d = number of dynamos

$1/d$ = number of cars

$100/d$ = number of cars to each dynamo one track

$200/d$ = cars to each dynamo both tracks.

$\frac{2000 \times 220}{d}$ = full load current of each dynamo

A rail weighing 80 lbs per yard has a cross section of 8/10 sq. ins. or $\frac{8}{7.854}$ circular inches or $\frac{8 \times 1{,}000{,}000}{7.854}$ circular mils nine

" $\frac{8 \times 1{,}000{,}000}{8 \times 7.854}$ circular mil of copper at full load,

" $\frac{8 \times 1{,}000{,}000}{16 \times 7.854}$ - - - - - 50% .

$\frac{8 \times 1{,}000{,}000}{12.5 \times 7}$ - - - - - -

$= 8000$ f.

With a 80 lb. rail 240,000 c. mils of copper.

Estimate for the cost of laying a Low Tension Street Railway

(100)

28th Sept.

Data:- Primary distribution from the termini of the line at a pressure of 1000 volts and 5% drop.

A motor dynamo at every 1000 feet of road or 5 to the mile. The capacity of this dynamotor to be double its full load output. The dynamo to deliver at 25 volts maximum, but the lowest pressure at mid-section to be 20 volts at full load. The drop in rails and armatures not to exceed 5 volts.

Double Track. Iron rails at 50% conductivity.

Cars 10 tons each, single, running 6 mph. and absorbing steadily 6 EHP = 4.5 KWH each. = 200 amps each.

Case I. Cars 1000 feet apart on same track. Road level.

Load on each transformer $400 \times 25 = 10$ KWH.

1.5 volts drop in dynamo leaves 3.5 volts drop on track. $\frac{2 \times 500 \text{ ft} \times 100}{3.5} = 28{,}000 = 310{,}000$ c. mils.

$310{,}000 - 250{,}000 = 60{,}000$ c. mils $\times 2 = 120{,}000$ c. mils of mains tubing along the road. $240{,}000 \times 3.015 \times 10^{-6} = 0.724 \times 3.015 = 0.72$ lbs. per foot

3800 lbs per mile $\$0.864$ per foot $= \$4862$ per mile.

Over 3 miles 16,000 feet 16 transformers of 20 KWH. capacity @ $\$70 = \$1120$ each

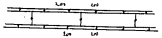
Transformers $21,000

Tubes 13,086

Ties 2280

$\$36,966 = \$12,322$ per mile.

Case II miles Cars 500 feet apart on same track. Road level.



Load on each transformer $800 \times 25 = 20$ KWH.

$\frac{500 \times 200}{1.75} = 56{,}000 = 620{,}000$ c. mils.

$620{,}000 - 250{,}000 = 370{,}000$ c. mils $\times 2 = 740{,}000$ c. mil tubing.

3.30 per foot $= \$17,420$ per mile

Transformers = 14,000 - -

31,420

Ties = 1,740

33,160 -

Case III Cars 250 feet apart on same tracks. Road level.

Load on each transformer $1600 \times 25 = 40$ KWH.

Conductivity 1,240,000 c. mils $= 250{,}000 + 1{,}000{,}000$ c. mils.

$\times 2 = 2{,}000{,}000$ c. mil of tubes. @ $7.40 per foot

$= \$39,100$ per mile

Transformers = 28,000 - -

Ties = 3,900

$71,000 -

Each 1% of grade on a 10 ton car adds a pull of 200 lbs. 6 mphs. = 8.8 ft per sec. = 1760 foot lbs. = 3.3 HP. @ 0.6 η = 5.5 EHP = 4.1 KWH. = 200 amp.

On the Winding of a Fan Motor for 500. volts 3rd Apt

The 120. volt motor has 750 turns of # 27 B.W.G. 0.016 D.c.c. & 0.022" on each spool at 6000 turns on the armature. For 500 volts it will be necessary to wound on 24,000 turns in all of # 33 B.W.G. 0.008" silk cond: & 0.011". There are four bobbins each in 8 divs = 750 turns to each quarter spool. There will thus be 32 commutator blocks.

Trial field winding # 31 B.W.G. 0.010" s.c.c.

Measurements of drop in (a) 2 KWT transformer rewound 3rd Sept. 91.

The coils were rewound with the primary outside the secondary

For curve see p. 98

No. of Obs.	Primary C	Load on A side	Load on B side	Dynamometer in B	✓	Amps in B	Volts on A	Drop in primary	Equivalent drop in 2ndary	Observed drop in 2ndary	Specific drop
1	0·2	0	0	0	-	-	121·	0·88	0·08		
2	0·5	7	0	12"	3·46	3·17	120·8	1·71	0·21	0·8	0·6
3	0·73	12	-	33"	5·7445	5·26	119·7	2·497	0·30	1·3	1·0
4	1·04	17	-	72	8·485	7·77	119·1	3·56	0·43	1·9	1·5
5	1·35	22	-	120	10·95	10·02	118·5	4·62	0·55	2·5	2·0
6	1·6	27	-	175	13·23	12·11	118·0	5·47	0·66	3·0	2·3
7	1·85	32	-	237.5	15·40	14·09	117·4	6·33	0·76	3·6	2·8
8	2·05	37	-	269	16·40	15·01	117·0	7·01	0·84	4·0	3·2
9	-										

Resistance of primary 3.421 ω @ 20°C.
" " secondary 0·1675 " " both

Inductances of the coils as wound in this manner

Res: 29.54 1000/a $3.58^{\#}$ = 105·8 h.

Mutual inductance 29·54 1000/a $(3.18^{\#}, 3.58^{\#}, 3.98^{\#})$ = 11·70 h.

Repeated measurements of drop with (b) 2 KWT transformer primary and shorted

No. of Obs.	Primary C	Load on A side	Load on B side	Dynamo	✓	Amp	Volts on A	Drop in primary	Equivalent drop in 2nd	Observed drop in 2nd	Specific drop
1	-	20	20	91"	3.016	2·				3·7	
2	0·2	0	0	-	-					0	
3	0·53	7	0	11·5	3·391	3.102	117.7	1·	0·22	0·3	0·08
4	0·75	12	0	32"	5·657	5.176	117.4		0·31	0·6	0·29
5	1·02	17	0	62"	7.874	7.204	117.2		0·42	0·8	0·38
6	1·34	22	0	108·5	10·41	9.524	116·9		0·55	1·1	0·55
7	1·60	27	0	159"	12·61	11.54	116·7		0·66	1·3	0·64
8	1·84	32	0	250"	15·81	14.47	116·6		0·75	1·14	0·65
9	2·1	37	0	274·5	16·56	15·15	116·5		0·86	1·50	0·64

For curve see p. 97.

Brethon Transformers C. E. L. Brown

Watts	500	1000	1500	3000	5000	7500	10,000	20,000
Kgms.	60	80	100	165	250	340	400	700
Lbs.	132·3	176·3	220·5	361·	551	749	882	1543
Watts per kgm	8·3	12·5	15	18	20	22·	25	28·5
Watts per lb	3·78	5·67	6·81	8·26	9·07	10	11·32	12·96

Transformer of Ganz & Co Buda Pesth.

Watts	750	1875	3750	7500	15,000
Kgms.	24·5	46	75	125	250
Lbs.	54	101·4	165·4	275·5	551
Watts per kgm	30·62	40·75	50	56	60
Watts per lb.	13·9	18·49	22·67	25·4	27·22
Iron kgms	18.0	30	50	90	165
lbs	39·7	66·2	110·3	198·5	363·8
Copper kgms	6·5	16	25	39	85
lbs.	14·33	35·3	55·1	86·0	187.4
C²R loss	2%	2%	2%	2%	2%
Hysteresis loss	6.6%	5·5%	3·5%	2·5%	1·5%
Comm. eff.	0·894	0·925	0·945	0·955	0·968

Transformer of Siemens + Halske

Watts	1,000	2500	5000	10,000
Kgms	40	80	130	211
Lbs.	88·2	176·4	286·6	465·2
Watts per kgm	25	31·25	38·46	47·4
Watts per lb	11·34	14·17	17·45	21·5
Comm. eff.	·891	0·94	0·96	0·96

T. H.

Lights	10	15	25	50	75	100
Watts	500	750	1250	2500	3750	5000
(Cuivre) Lbs.	67	92	165	297	470	825
Watts per lb.	7.46	8.15	7.58	8.42	7.98	9.52

Westinghouse

Lights	5	10	15	20
Watts	250	500	750	1000
Unwound Lbs.		30		55·5 lbs
Encased				605 -

Edison

Lights	10	20	40	80	100
Watts	500	1000	2000		5000
Lbs. copper	5·5	11·75	25 lbs		62
Lbs. iron	31·	48·8	98 lbs		135
Total Lbs.	36·6	60·5	96 lbs		197
Total encased	84	110	138 -		
Watts per lb.	13	16	28 lbs		25.
do encased	6.	9·0	10·6		

Particulars of various types of Transformers.

Stanley

Lights	30
Watts	1500
Weight	53½
" encased	91½
Watts per lbs.	28
" " encased	16·4

Slattery

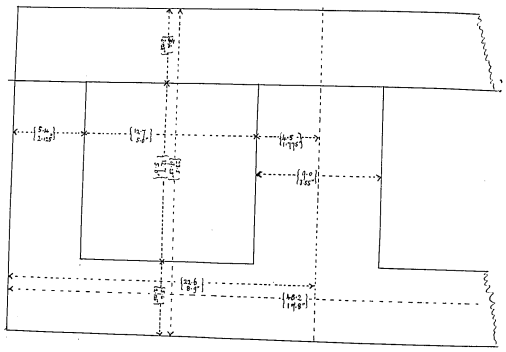
Lights	30
Watts	1500
Weight	75
" encased	126
Watts per lbs.	20
" " encased	12

National

Lights	20
Watts	1500
Weight	
" encased	104½
Watts per lbs.	
" encased	

Half sized Section of transformer through plane of plates.

Width finished 85 cms



(103)

Design for a transformer of 80 light or 4 KWT capacity.

Primary effective voltage	=	1000 volts
Secondary " "	=	120 " at no load
Primary current at full load	=	4.3 amp.
Secondary " " "	=	16.6 say 17 amp.
Primary winding	=	700 turns of # 12 B.W.G. 0.109" d.c.c. & 0.124"
Secondary "	=	168 " " two # 9 B.W.G. wire 0.148 d.c.c. & 0.163" brought out at the 84th turn for neutral.
Length of mean turn	=	4 × 0.70 = 2.80' = 85.34
" " primary winding	=	700 × 2.8 = 1960' = 597.38 cms.
" " secondary "	=	168 × 2.8 = 600' = 182.85 "
Weight " primary "	=	70.56 lbs.
" " secondary "	=	39.8 " × 2 = 79.6 lbs.
Total weight of copper	=	~~149~~ 150.2 lbs.
Res: of primary	=	2.195 Ω @ 100°C. 1.95 Ω @ 60°C. 1.704 Ω @ 20°C.
" " secondary	=	0.1821 Ω @ 100°C. 0.1617 Ω @ 60°C. 0.1414 Ω @ 20°C
Drop in primary at load	=	9.5 volts = 1.14 volt equivalent in 2ndary. @ 100°C.
" " secondary	=	3.11/2 volt = 1.55 " at 100°C.
Total secondary drop	=	2.7 volts on each side. (120 − 117.3.) @ 100°C.
Mean length of mag: ckt.	=	69 cms.
Cross-section of central core	=	9 × 8.5 = 76.5 sq: cms. × 0.93 = 71.14 sq: cms.
" " rest of core	=	10.8 × 8.5 = 91.8 sq: cms × 0.93 = 85.4 " "
Assumed value of Φ	=	~~160,000~~ 226,800
Maximum " " $\mathcal{B}$	=	~~2,050~~ 3,188
Area of air gaps	=	9 × 8.5 = 76.5 and 10.8 × 8.5 = 91.8 sq: cms.
Winding space section	=	12.7 × 12.7 = 161.3 sq: cms. = 25 sq: in.
$\mathcal{S}/A$ of mag: ckt	=	12.7/71.14 + 5.4.3/85.4 = 0.1785 + 0.6336 = 0.8145
Space occupied by primary	=	700 × 0.124 × 0.124 = 10.76 sq: in 69.42 sq: cms.
" " " secondary	=	168 × 2 × 0.163 × 0.163 = 8.93 " " 57.5 " "
Total space occupied	=	19.69 " " 126.92 " "
Coefficient for practice + ins:	=	1.27.
Surface of iron on one side	=	45.2 × 23.5 − 2 (161.3) = 1062 − 332.6 = 729.4 sq: cms
" " " top	=	9 × 45.2 = 406.8 sq: cms.
" " " other side	=	9 × 23.5 = 209.5
Total surface of iron	=	2 (729.4 + 406.8 + 209.5) = 2691 sq: cms.
" volume " "	=	8.5 × 729.4 × 0.93 = 5770 c.c.
" mass " "	=	45.0 kgm. = 99.2 lbs. without rivet plate

Weight of transformer proper = Iron plates 99. lbs.

				$ per lb.
	Rivets + rivet plate	7.		
		106	@ 0.05 =	$ 5.30 0.066
	Copper	150...	@ 0.20 =	$ 30.00 0.375
		256		$ 35.30 0.1441
	Clamps	10.		
		266.		

Primary waste in copper by $\mathcal{S}^2$ $(4.3)^2 \times 2.2$ = 40.6

Secondary " " " " $17^2 \times \frac{0.364}{2}$ = 52.3

Hysteresis 92.9

10%

Estimated Total loss 200.

Efficiency estimated $\frac{4000}{4200} = 0.95$

Tests of a sample of ~~copper~~ wires presented to the Laboratory by Dr Waldo of Bridgeport Conn. 3rd Oct.

This sample of wire was about ten feet long and resembled copper in appearance. Dr Waldo gave its conductivity as 97% of Matthiessen standard, it temp: coefficient at zero, and its tensile strength as 120,000 lbs: per sq: inch. Some wires twisted up with about 20 twists per inch, to tensile strength 85,000 lbs. per sq: in:

Two pressure wires were soldered on about 5 cms. from the ends, and the distance between them found to be 334·7 cms. The diameter from a mean of 8 measurements was 0·2901 cm. 0·1143" #9 B+S. The specific gravity obtained for two short lengths was

Weight in air	2·5381	1·4672
" " sp: dist @ 18°c.	2·2332	1·2916
Loss.	0·3049	0·1756

Sp: g: 8·324 . 8·355 Mean 8·3395

The wire was coiled into a spiral and varnished. It was then immersed in oil and the resistance between pressure wires measured by comparison on a differential galvanometer with the standard 0·1 ω. as follows:-

Res: of Galvo 5413·3 ω @ 18·8c. = 2706·7ω per coil

Balance between Std 0·1 ω @ 20·3°c = 0·1000 5ω and length of wire between pressure conductors. 4170ω added to 0·1ω side.

Resistance of wire 0·2514 ω @ 20·3c.

The bath was now heated until a temp: of 355° F was reached when the balance was 4·235 ω. 0·2563ω.

After cooling down to 70°F 4·125 ω 0·2523ω. } 1·076 for 159°c.

a coefficient of 0·01 %. per °C.

The resistance per cm. = $2·523 \times 10^{-1} / 334 \times 10^{3}$ = $7·538 \times 10^{-10}$ = $7·538 \times 10^{4}$ a.E.M.U

" " " a.c. = 753,800X 066624 = 49930 : or 3·2% cond: of copper

Repeated tests on 6th as follows

Galvo: res: 5420 ω @ 21·6°c. compensated = 2710 ω per coil

Res: added to wire for balance 4110 ω against 0·1ω @ 22·1°C. wire 0°C.

" " " " " 4076ω " " - 20·7c. -14°

" " " " " 4130ω " " " 20·4

2710	2710	2710
4110	4076	4130
6820	6786	6840

This represents 0·2502ω @ -14°C

0·2517 ω - 0 - 00013/25 = 0·52 % for 14°c = 037 %

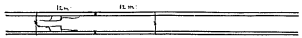
0·2522ω " + 20·4 0·0007/25 = 0·28 % " 20·5°c = 014%

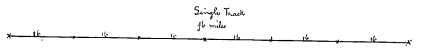
0·0020/255 = 0·8 % " 34·4 = 0·025 %

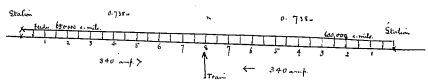
The best result is 0·014 % per °C.

Data and experiments with a small alternating current Fany Motor. 6th Oct.

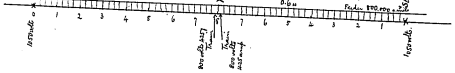
This motor is built by the Excelsior Co for 50 volt alty: circuits. It drives a fan at a good speed absorbing about 4 amp. and little power. It has solid metal connections between coils and commutator bars. These are of iron or steel 0.022" diam and about 3" long. The armature is an ordinary drum and the machine operates on continuous currents. Short circuiting all the row connectors with strips of copper caused the brushes to spark. They do not show any spark normally. The iron wire get red hot in still air at 5·5 amps and melt at about 7·5. The res: of the armature is 0·3ω the field 2·66ω series wound = 3·0 ω.







1,000,000 circ: mils weigh 3.4 tons lbs: per mile and cost $4,000 per mile one way
1,000,000 " " " " 0.058 ω per mile say 0.06 ω



Traction Calculations of copper for Electric Railroads. (105)

1st Case. Sections 24 miles long, fed at each end. One train on each track in each section.
Each train to weigh 100 tons and to be capable of making 50 miles an hour on a 1½ % grade.
Train friction 7 lbs: per ton = 700 lbs. Gravitation pull 1000 lbs.
Total pull 1700 lbs. 50 m.p.h. = 73.3 ft: per sec: = 124,610 foot lbs. per sec: = 226 H.P. = 170 KW.
Rail has a cross section of 3 sq. in: and has therefore an equivalent of 240,000 c. mils of copper @ 50% conductivity of rail.
Track rail 80 lbs. each making 720,000 c. mils. copper or same loss.
Allowing a drop from 700 to 500 volts in the mains at the lowest point and a motor of 75% com: eff. = 227 KW. = 454 amps. ⅓ of the drop will be in the center rail or 150 volts, so that the main res: will be 47/225 ω = 0.6 ω. from lowest point to feeding point at 4.6 × 10⁻⁵ ω per foot = 13,000 feet.
With 250 volts drop in the feeder, and ⅔rds. of the load of each train = 300 amps: per train = 1200 amps: full capacity or 1200 KWH full power of stations. 300 ∫ carried 9 miles for 350/2 or 125 volts drop = 300 × 47,000 / 125 = 112,800 K = 1,240,000 circ: mils. of copper

Allowing 150 tons as the weight of a passenger train 50 mph.
400 " " " " freight 15 " "
7 lbs per ton train res: and 0.5% grade everywhere.
Power for passenger trains on this basis 2500 lbs pull 340 H.P. 250 KW: say.
" freight 6800 " 330 H.P. " "
At an efficiency of 0.75 = 340 KW. electrical in each case
At 600 volts = 567 amps. At 700 volts = 485 amps. At 500 v. 680 amps.
With a ground return circuit, 240,000 c. mils of copper in central rail
150 volts drop in the central rail for 680/2 amps = 150 lbs / 340 = 0.44 ω.
Track fed at every mile & half mile.
At the 8th mile suppose one train completely supplied by the station, that is two trains in midsection. Allow 250 volts drop in feeder = 680 amps × 680 × 8 × 5280 / 250 = 1149,900 = 1300,000 c. mils.
The weight of this would be 3.91 lbs: per foot = 20,700 lbs: per mile @ $0.21 $5,175 per mile.
If it were impossible to run more than one train in a section, then at the center the current would be supplied equally from each end and 650,000 c. mils would suffice. = $3,600 per mile
The total power called for would be 2 × 340 = 680 KWH.
Two trains supplied at maximum from one power station.
650,000 c/mile = 0.0923 ω per mile and eight mile = 0.7384 ω
340 × 0.738 = 250 volts.
If the rail were tied up with the feeder every quarter of a mile, the drop in the rail might be neglected, and the pressure sustained uniformly at 800 volts would be equivalent to 340 KWTs at 425 amps.
If two trains were in the middle of one section at one time so that 425 amps: were supplied from one end at 250 volts drop over 8 miles = res: of 250/425 = 0.6 ω = 0.075 ω per mile = 800,000 circ: mils. = $. 3,200 per mile

Tests of two short lengths of lead covered cable from Schenectady Works. 3rd Oct.

These lengths were received on the 3rd Oct: from Schenectady Works.
They were marked as 200-foot lengths of lead covered paper insulated (cable/telephone)
The length measured was 211 feet (210 for 1 and 212 for the other).
The weight of one length was 105 lbs for 210 feet = 0.5 lbs. per foot.
External diameter 0.5" over lead. (1.27)
Internal " 0.378" under - (0.952)
Diameter of the copper wire 0.04.03" (0.1023) #18 B+S.
Diameter of wrapped paper insulation 0.125" (0.3175)
Seven wires stranded. Single conductor.

No. of Obs.	Wires	Stranding Wires	No. of Wires	Mean Thickness	Capacity $\frac{K}{9}$	Capacity per mile $\frac{K}{9} \times 2240$	Mean Thickness for 1 Mile	$\frac{M}{9}$	$\log_{10}\frac{M}{9}$	$Fog\frac{M}{9}$	$\frac{1}{Fog\frac{M}{9}}$	Abs: Insul:	Insul: per mile of 2240 feet
1	1(a)	sheathing	7	93·5	0·00390	0·8677	73·5	1·272	0·104449	0·465 X 10^{11}	1·622 X 10^{11}	427,700 Ω	1,689 Ω
2	1(b)	sheathing	5	92·6	0·005243	0·11662	63·5	1·458	0·16376	9·568 "	1,042	27,150 Ω	1,085 Ω
3	1(a)	2 (a) & sheathing	12	112·3	0·007091	0·1773	91	1·2344	0·09132	6·474 "	1,545	402,600 Ω	1,609 Ω
4	1(b)	2 (a) & sheathing	14	112·5	0·007096	0·1776	78	1·4423	0·15897	11·28 "	886·5	231,000 Ω	923 Ω
5	1(a)	2 (a)	2	67·5	0·004226	0·1066							
6	1(b)	2 (b)	3	65·7	0·004145	0·1037	34	1·921	0·28353	14·75 "	851·1	221,800 Ω	886 Ω
7	2(a)	3 (a)	2	71·5	0·004511	0·1129							
8	2(b)	3 (b)	1	68	0·004290	0·1074	46	1·889	0·27623	11·85 "	843·9	220,000 Ω	879 Ω
9	2(a)	4 (a)	2	64	0·004038	0·1010							
10	2(b)	4(b)	2	61	0·003848	0·0963							
11	2(a)	5"(a)	2	64	0·004037	0·1010							
12	2(b)	5(b)	2	62	0·003912	0·0979							
13	5"(a)	sheathing	3	115·3	0·007270	0·1820	94	1·226	0·08849	6·438 "	155·3	405000 Ω	1618 Ω
14	5"(a)	(2)(4)(5) sheathing	3	126	0·007948	0·1989	100	1·260	0·10037	7·978 "	125·3	326500 Ω	1305 Ω
15	5(b)	(2)(4)(5) sheathing	4	123	0·007757	0·1942	90	1·364	0·13577	10·53 "	94·97	247500 Ω	989 Ω

The mean charge and discharge from 0·010 ♀ = 158·5 divs same 50 Mfds.
The conductor res: of all 7 wires in cable as @ 21·6°c = 9·75 - or 1·393 ohms = 30·85 Ω
- - - - - - - - - - (b) - - - = 9·68 - = 1·383 - = 30·60 Ω
The above insulations being somewhat low compared with those found at Schenectady, repeated the test on the following day with paraffin wax over the ends of the cables and all 7 wires in each connected.
10 Mfds length 420 X 7 = 2940 feet of conductor Capty 191 divs throw 0·05 ♀ 15·4 divs = 0·0553 ♀
or 0·069 ♀ in all 7 wires per mile = 0·0991 ♀ per wire per mile under these conditions. The charge fell to 163 in 1 min = 1·054 $\log_{10}$ = 0·02277 = 0·05 mic ♀ = 227,200 Ω
160 - 2 - = 1·064 = 0·02697 ♀ = 0·00593 = 59,200 Ω
154 - 5 - = 1·112 = 0·00610 = 0·002550 = 57,100 Ω
20°c.

results equivalent to 42,650 Ω per mile at 1st min
18,120 - - - 2nd -
28,460 - - - 5th -

Both the central wires and grounding) all the others on the sheath took
the charge = 222 and after 5 mins: insulation 133 with 0·01 ♀ 157.
Capacity = 0·01414 or 0·1766 ♀ per mile $\frac{222}{133}$ = 1·669 $\log_{10}$ = 0·22246 X 0·01414 = 0·003146
317·8 X 1303 = 141,410 Ω abs. = 3,313 Ω per mile.

3250 / 211 = 25·025

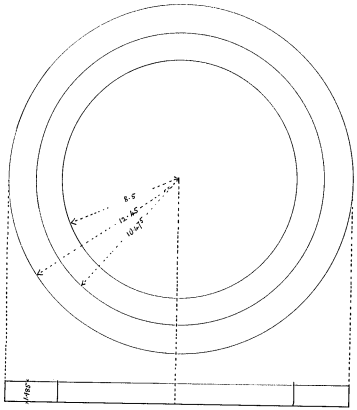
Full sized
Cross section

Taking an air-condenser of electrodes 0·04.03" and 0·375" in diameter,
the ratio is 9·305 $\log_{10}$ ratio = 2·2305 $\frac{K}{4\cdot461}$ = 0·22416 X
0·1788 = 0·0241 ♀ per mile.

Taking the diameters as 0·04.03" and 0·125"
the ratio is 3·101 $\log_{10}$ ratio = 1·1314 $\frac{K}{1\cdot1314}$ = 0·8842 X 0·1788 = $\frac{0\cdot158\ ♀}{2}$ per mile

Taking the diameters as 0·04.03" and 0·218
the ratio is 5·236 $\log_{10}$ ratio = 1·655 $\frac{K}{1\cdot655}$ = 0·6042 X 0·1788 = $\frac{0\cdot1108\ ♀}{2}$ - -

Half sized plan and diametrical section of ring



External	Radius	12·45	Diameter	24·90	Circumference	78·22	R^{v} 155·00
Internal	"	8·50	"	17·00	"	53·40	" 72·25
Mean	"	10·475	"	20·95	"	65·81	" 109·7

Annular area 260·0

Radial breadth 3·95

Depth in plate 55

Mean Thickness of each 0·027

Depth in air 1·485

Cross section 5·865 sq. ins.

Volume 386·1 c.c.

Weight in air 2699 gms.

Sp. g. 6·99

Cross section assuming Sp. g. of 7·8

5·258 sq. ins. = depth of 1·331

Winding 2 secondaries of 50 turns each

Primary 1st layer 337

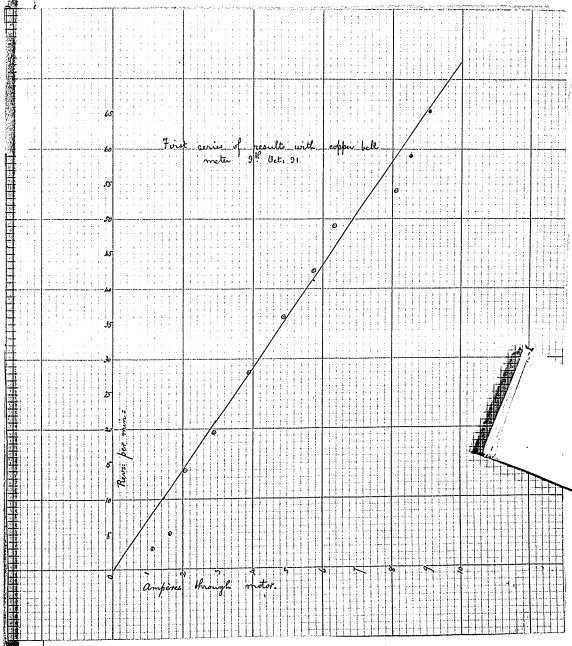
2nd " 392

3rd " 368

Total 1097

Particulars of a ring of annular iron plates 0.009" thick cut from sheet iron received from Schenectady.

(107)


First series of results with copper belt
made 9th Oct. 91.
Revns per minute
Amperes through motor.

Design for a Sewing Machine Motor to be operated by battery.

The battery is to consist of seven cells, each to have 0.72 volts and 0.03Ω internal resistance, or totals of 5 volts and 0.21 ω. With 5 amperes this means 1 volt drop or 4 volts at motor terminals. Allowing 1 volt drop in motor the back emf. of the motor at 1800 r.p.m. is to be 3 volts

$\Phi = 80{,}000$ $n = 13{\cdot}3$ $\therefore w = 300$ Or 75 turns on each ⊓ spool = 37·5 on each half spool. There are 2·22 sq. cms. of winding cross section on each spool allowing 0·06 sq. cms or 0·0093 sq. in to each wire = $9{\cdot}3 \times 10^{-3}$ or $9{\cdot}44 \times 10^{-3}$ sq. in. = 0·096 to each wire diam. covered = 0·072" # 15 B.W.G. The mean turn is 0·38' so that 37 turns = 12·95' × 0·0015 ω = 0·0195 ω say 0·02 ω Eight such = 0·16 ω and res. of armature 0·04 ω. Drop will 5 amp. 0·2 volt

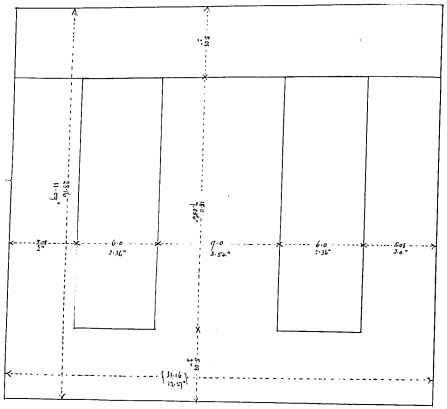
The field winding to be half series and half shunt.
An MMF of 2000 is required = 1600 amp. turns of which 800 amp turns = series 1·5 lbs. of wire 5 amp × 160 turns at 0·5' per turn = 80 feet - # 18 B.W.G. 1·5 lbs. @ 0·075 ω - 0·11 ω = 0·55 volt drop. Total series drop 0·75 volt
Shunt winding ¼ th amp. 2400 turns. 20 ω = 12000 feet. - 60 feet per ω. 23 ozs = 2lb. 3oz. Total weight of copper on fields 3·75 lbs.

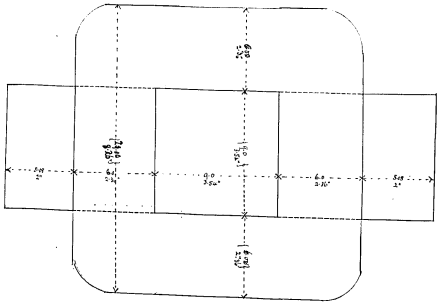
Test of Experimental Copper Ball motor 9th Oct. 91.

The meter is connected direct from its spindle to the recording brain whose lowest counter reads 5 times less than the number of ball revs.

Obs.	No. Flumps	Obsvd.	Amps.	Time	Revs.	Rs per min	R.p.a.c.		
1	2	0·226	1·166	60 sec	3	2·77			
2	3	0·3195	1·623	59.	5	5·08			
3	4	0·295	2·039	1 min	13	13			
4	6	0·56	2·890	-	19·5	19·5			
5	8	0·745	3·845	-	28	28			
6	10	0·95	4·902	-	36	36			
7	12	1·115	5·753	-	42·5	42·5			
8	14	1·235	6·372	-	49	49			
9	16	1·57	8·10	-	55	55			
10	18	1·66	8·566	-	59	59			
11	20	1·76	9·082	-	65·5	65·5			
12	1								

Plan and Section half-size of Transformer





Design for a revised type of E Transformer 80 lights 2 HWTs.

109

Primary effective voltage	=	1000
Secondary - -	=	120 volts at no load.
Primary current at full load	=	4·3
Secondary - - - -	=	16·6 say 17. amp.
Primary winding	=	700 turns of #12 B+S. 0.081" d.c.c. & 0.095"
Secondary -	=	168 - - #8 B+S. (double (in 2) with the 84 turns 0.129" d.c.c. & 0.145" brought out for 3-wire.
Length of mean turn	=	48 × 4 = 60 cms. = 2'
Length of primary winding	=	1400'
" " secondary "	=	336'
Weight of primary	=	27·7 lbs.
" " secondary	=	33·6 "
Total weight of copper	=	61·3 "
Res: of primary coil	=	2·85 ω @ 100°C 2·53 ω @ 60°C. 2·2144 ω @ 20°C.
" " secondary "	=	0·1353 ω " 0·120 ω " " 0·105 ω " "
Drop in primary at loads	=	12·35 volts = 1·54 volts equivalent in 2ndry at 100°C.
" " secondary " "	=	2·30 " = 1·15 " " " " "
Total 2nd drop . .	=	2·69 - at 100°C. on each sides.
Mean length of Magn: cct.	=	65 cms.
Gross section of central core	=	9 × 8·5 = 76·5 ~~and 10·8 × 2·5 = 27·0 sq: cms~~ × 0·93 = 71·14
" " rest of core	=	10·16 × 8·5 = 86·34 × 0·93 = 80·3 sq: cms.
Assumed value of Φ	=	160,150
Maximum " " B	=	2,250
Area of air gaps	=	9 × 8·5 = 76·5 and 10·16 × 8·5 = 86·34 sq: cms.
L/A of Magnetic circuit	=	18/71·14 + 47/80·3 = 0·253 + 0·585 = 0·838
Space occupied by primary	=	700 × 0·095 × 0·095 = 6·315 sq: ins:
" " secondary	=	336 × 0·02076 = 6·966 " "
Total space occupied	=	13·281 sq: ins:
Winding space allowed	=	6 × 18 = 108 sq: cms. = 16·74 sq: ins.
Coefficient of magn:	=	1·26.
Surface of iron on one side	=	31·16 × 28·16 − 2(108) = 877·4 − 216 = 661·4 sq: cms.
" " top	=	9·0 × 31·16 = 274 sq: cms
" " side	=	9·0 × 28·16 = 253 " "
Total surface of iron	=	2 (661·4 + 274 + 253) = 2577 sq: cms
" volume "	=	9·0 × 661·4 = 5952 c.c. × 0·93 = 5536
Sp: gr:	=	7·8
Mass "	=	43,200 gms. = 95·2 lbs. without rivet plates
Weight of transforms proper	=	95·2 lbs. on probably) includes rivets @ 08 = 3760
Copper	=	61·3 " @ 20 - 12·26
Clamps	=	10 17·02 @ 0·215 per lamp
		166·5 "

Primary waste by ct	=	$4.3^2 \times 2.85$ = 53·5 Watts
Secondary " "	=	$17^2 \times 0.135$ = 39 Watts
		Total ct 92·5 "
		Hysteresis 117·5 "
		Total loss 210 "

Estimated commercial efficiency $\frac{4}{4.3}$ = 0·93

Calculation of the Maximum Economy of material in constructing Transformers of the B type, neglecting leakage drop.

Let c be the ceiling space section in groove allowed (sq: cms.)
b " " breadth of the groove - cms.
mb " " height " " " " so that $c = mb^2$
ρ " " working resistivity of the ceiling space under practical conditions
N " " number of turns in the primary coil
$\frac{N}{n}$ " " " " " secondary "
ρ " " resistance of the primary in A E M U.
σ " " " " secondary " "
σ " " sp: gr: of the copper ceiling space under practical conditions
i " " " " " iron in the core " "
ϕ " " price of copper per gramme in cents
q " " " iron " " "
P " " price of wire and copper in the transformer (cents)
K " " side of the central core in cms.

Then $\rho = \frac{8 N^2 \rho (b+K)}{c}$ and substituting for $b = \sqrt{\frac{c}{m}}$

$$c\phi = \frac{8 N^2 \rho \left(K + \sqrt{\frac{c}{m}}\right)}{\rho}$$

Area of copp^r $= 4(b+K)c = 4c\left(K + \sqrt{\frac{c}{m}}\right)$

Weight " $= 4\sigma c \left(K + \sqrt{\frac{c}{m}}\right)$

Price " $= 4\phi\sigma c \left(K + \sqrt{\frac{c}{m}}\right)$

Mean length of wire $= 2b(m+1) + 2K$

" volume of iron $= 2\frac{K^2}{2}\{2b(m+1) + 2K\} = K^2\{b(m+1) + K\}$

" $= 2K^2\left\{\sqrt{\frac{c}{m}}(m+1) + K\right\}$

" weight $= 2K^2 i \left\{\sqrt{c}\frac{(m+1)}{\sqrt{m}} + K\right\}$

" price $= 2K^2 q i \left\{\sqrt{c}\frac{(m+1)}{\sqrt{m}} + K\right\}$

$$P = 4\phi c\sigma\left(K + \sqrt{\frac{c}{m}}\right) + 2K^2 q i \left\{\sqrt{c}\frac{(m+1)}{\sqrt{m}} + K\right\}$$

$$\frac{dP}{dm} = -2\phi c\sigma\frac{\sqrt{c}}{m\sqrt{m}} + 2K^2 q i \sqrt{c}\left(\frac{\sqrt{m} - (m+1)\frac{1}{2\sqrt{m}}}{m}\right)$$

$$\therefore \frac{2\phi c\sigma\sqrt{c}}{m\sqrt{m}} = \frac{1}{2}K^2 q i\sqrt{c}\,\frac{(2m^2+m+1)}{m\sqrt{m}}$$

$$2\phi c\sigma m\sqrt{m} = K^2 q i \sqrt{c}\,(2m^2+m+1)$$

$$2m^2+m+1 = \frac{2\phi c\sigma m}{K^2 q i}$$

$$m^2 + m\left\{\frac{1}{2} - \frac{2\phi c\sigma}{K^2 q i^2}\right\} = -\frac{1}{2}$$

$$m = -\left\{\frac{1}{4} - \frac{\phi c\sigma}{K^2 q i}\right\} + \sqrt{\left\{-\frac{1}{2} + \left(\frac{1}{4} - \frac{\phi c\sigma}{K^2 q i}\right)^2\right\}}$$

$\frac{\phi}{i} = 5$ $\frac{\sigma}{i} = 1$ K and c are given

$$m = -\left\{\frac{1}{4} - \frac{5c}{K^2}\right\} + \sqrt{\left\{-\frac{1}{2} + \left(\frac{1}{4} - \frac{5c}{K^2}\right)^2\right\}}$$

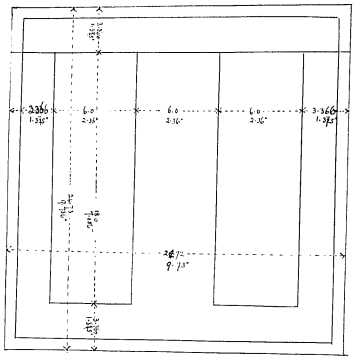
Let $K = 9$

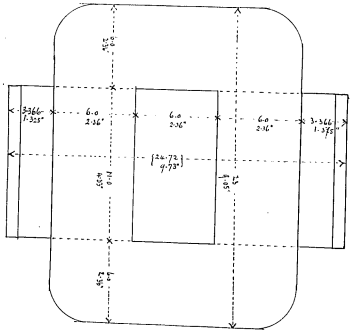
$$m = \left(\frac{5c}{81} - \frac{1}{4}\right) + \sqrt{\left\{-\frac{1}{2} + \left(\frac{1}{4} - \frac{5c}{81}\right)^2\right\}}$$

If $c = 100$

$$m = (6.17 - 0.25) + \sqrt{5.92^2 - 0.5}$$
$$= 5.9 + 5.9 = 11.8$$

Plan and Section of Transformer. Half size.





Modification in design for an E Transformer of 4 KW.T. or 80 light capacity. (111)

Primary Effective voltage = 1000 volts at terminals
Secondary - - = 120 volts at no load
Primary current at full = 4·3 amp.
Secondary current at full load = 16·6 or 17 amp
Primary winding = 700 turns of #12 B.&S. 0·081" d.c.c. to 0·095"
Secondary - = 168 - - #8 B.&S. (double) 0·129" d.c.c. & 0·1144"
84 lb double turns brought out for 3-wire.

Length of mean turn = 58 cms = 1·90'
Length of primary = 1330'
- - secondary = 319·5'
Weight - primary = 26·32 lbs.
- - secondary = 32·0 -
Total copper wire = 58·3 -

Res: of primary coil = 2·71 = @ 100°C, 2·405 = @ 60°C, 2·103 = @ 20°C.
- - secondary coil = 0·1285 = - - 0·1144 = - - 0·1 = - -

Drop in primary at load = 11·75 volts - 1·47 volts drop in the secondary
- - secondary - = 2·2 1·10 - - - - -
Total or drop in Duty. - 2·57 - @ 100°C.

Mean length of Mag cct. = 59 cms.
Cross section of central cm = 10·2 × 6·0 = 61·2 sq. cms × 0·93 = 56·9 sq: cms.
- - - outer cms = 10·2 × 6·73 = 68·8 - - × 0·93 = 64·0 - -
Assumed value of Φ = ~~Maximum~~ 226,800
Maximum - - B = ~~2·677~~ 3,986
Area of air gaps = 10·2 × 6·0 = 61·2 and 10·2 × 6·73 = 68·8 sq: cms
L/A of magnetic cct. = 18/86·9 + 41/64 = 0·316 + 0·641 = 0·957

Space occupied by primary = 700 × 0·095² = 6·315 sq: in.
- - - secondary = 336 × 0·0208 = 6·966 - -
Total space occupied = 13·281 - -
Winding space allowed = 6 × 18 = 108 sq: cms = 16·74 sq: in.
Coefficient of magn = 1·26.

Surface of iron on one side = 24·73 × 24·73 − 2(6×18) = 611·57 − 216 = 395·6 sq: cms
top = 11·0 × 24·73 = 271 sq: cms
Side = 11·0 × 24·73 = 271 - -
Total surface of iron = 2 (395·6 + 540) = 2 × 937·6 = 1875·2 sq: cms.
- volume - = 10·2 × 3·937 = 40·35 cu: cms × 0·93 = 3753 c.c.
Sp. g. = 7·8
Mass = 29·28 kg. = 64·55 lbs. without rivet plates.

Weight of transformer proper = 64·55 lbs. iron in core @ 0·05 = $3.228
- - clamps &c = 20· 0·05 = 1·00
- - Iron = 84·5 4·23 or 0·053 per lb.
Copper = 58·3 - 0·20 = 11·66
14·28 15·89 0·198 - -

Primary cct work = 4·3² × 2·71 = 50·8
Secondary - - - = 17² × 0·13 = 37·5
88·3
Estimate Hysteresis 211·7
300 Watts

Estimated commercial efficiency = 93 %

Recalibration of Unifilar Wattmeter 13th Oct: 91.

The suspended coil was removed, emptied, and rewound with 460 turns of #30 B.W.G. 0.012" d.s.c. in 23 layers of 20 turns each or 460 turns in all. The res: of this coil after completion in oct: with the previous suspension wire 1000/100 Res: 8.13Ω @ 20°C. Ind: 8.57 − 1000/100 0.347 = 2.97 h.

Recalibrated the instrument as follows—

No. of Obn.	Coil No.	Voltage	Res.	Current in unit cent	Ramp	Obsvtn	Amp in fixed unit	Co	τ	α	Mean α	Corrected to Standard Conditions
1	1	126	16,500	0.007636	7	0·653	3·37	2573×10^{-3}	16°	1.608×10^{-2}		
2			8,490	14.84×10^{-3}	14	1·210	6·243	92·66 -	61'	1·519 -		
3			4,080	31·8 -	14	1·215	6·27	187·5 -	130'	1·519 -		
4			16,730	3.644×10^{-3}	14	1·215	6·27	187·1 -	111'	1·805 -	1.538×10^{-2}	1.552×10^{-2}
5	2	-	16,500	7.636×10^{-3}	1	0·0935	0.4774×10^{-2}	3.440×10^{-2}	336·5'	1.577×10^{-2}		
6		-	-	-	1	0·095	0·4903	3·744 -	24'	1580 -		
7		-	-	-	2	0·194	1·0	7·636 -	50'	1527 -		
8		-	-	-	3	0·314	1·621	12·38 -	76·5'	1·616 -		
9		-	-	-	4	0·405	2·09	15·96 -	101'	1·581 -		
10		-	-	-	6	0·594	3·062	23·28 -	141'	1·644 -		
11		-	-	-	8	0·742	3·828	29·24 -	193·5'	1·517 -		
12		-	-	-	10	0·936	4·831	36·89 -	235'	1·570 -		
13		-	-	-	14	1·329	6·337	48·39 -	324'	1·614 -	1.583×10^{-2}	1.579×10^{-2}
14	3	-	14,500	7.636×10^{-3}	1/2	0·040	0·2065	1.577×10^{-2}	61'	3.453×10^{-2}		
15		-	17,230	7·398 -	1	0·095	0·4897	3·744 -	130·5	2·693 -		
16		-	17,220	7·423 -	2	1·175	0·1903	6·686 -	265'	2.519×10^{-2}	2.612×10^{-2}	
17	4	-	17,180	7.332×10^{-3}	1/2	0·040	0·2065	15.14×10^{-2}	172'	8.8×10^{-2}		
18		-	17,080	7·390 -	1	0·093	0·1428	3·163 -	365"	8·25 -	8.525×10^{-2}	8.614×10^{-2}

It was found that in the case of #1 coil which has only 2 turns insufficient attention had been paid to the electromagnetic effect of the instrument leads. The constants was repeated with a double cord of leads.

No. of Obn.	Coil	Voltage	Res.	Current in unit cent	Lamp	Obsvtn	Amp in fixed unit 0·0511	Co	τ	α	Mean	Emf in Unit
1	1	122	7015	0·016	6	0·498	2·60		29·5	1.431×10^{-3}		0·017
2		-	3562	0·0314	4	0·479	2·60		61'	1·299 -		0·038
3			4092	0·0305	8	0·650	3·38		70·25'	1·370 -		0·032
4			3972	0·0307	7	0·576	3·00		66·5'	1·395 -	10^{-3}	0·032
5			3702	0·0330	6	0·502	2·62		64'	1·314 -	1·387	0·032
6	2	122	17,015	0·00717	4	0·320	1·67		83·25	1.430×10^{-2}	10^{-4}	0·009
7			17,415	0·00701	6	0·502	2·62		127·5	1·439 -	1·43115	0·009

Repeated calibration on Oct. 16th employing potentiometer for measuring currents

No. of Obn.	Coil	Voltage	Res.	Current in unit cent	Lamp	Obsvtn	Amp in fixed unit	Pdtl. in unit cent	Pdtl. in fixed unit	Co.	τ	α	Emf unit
1	1	126	8555	0·01473	6	0·520	2·712	0·01476	2·692	3.964×10^{-2}	27·5'	1.442×10^{-2}	0·017
2		"	4·165	0·03026	6	0·521	2·717	0·03112	2·728		57·5	1·436 -	0·032
3			4·145	0·03039	7	0·585	3·050	0·03112	3·068	9.112×10^{-2}	66·0	1·385 -	0·031
4	2	"	17,565	0·00717	4	0·340	1·773	0·00698	1·772	1.337×10^{-2}	89·0	1·390 -	0·008
5		"	17,175	0·007336	5	0·431	2·247	0·00736	2·236	1·0776	111·	1·384 -	0·008
6		"	17,315	0·007276	6	0·520	2·711	0·00728	2·714	1·0776	136'	1·453 -	0·008
7		"	17,265	0·007295	8	0·671	3·499	0·00728	3·568	2·098	177"	1·1168 -	-
8		"	7965	0·01592	3	0·252	1·322	0·01596	1·298	2·0577	142·5	1·1435 -	0·017

The mean values of the constants from these observations are :—

No 1. 1.398×10^{-2}

" 2 1.438×10^{-2}

" 3 2.585×10^{-2} ?

" 4 8.525×10^{-2} ??

This investigation only considers the original outlay) economy and not the greatest annual economy) which differs by considerable reason of variation in running expenses with varying percent of generating plant.

$$o = \ell/R$$

cost per foot = κo

Total cost of copper = $\kappa l o$

Cost of entire plant C = $Pm + \kappa l o + g(\mathcal{E}\gamma + \frac{\gamma^2 \ell}{o})$

$$\frac{dC}{do} = \kappa l - \frac{g\gamma^2 \ell}{o^2}$$

$$o = \gamma \sqrt{\frac{g}{\kappa}}$$

One c.mil. foot = 11ω and weighs 3.015×10^{-6} lbs. cost $0.25 = 7.54 \times 10^{-7}$ $\$$.

1ω per foot = 33.17 " " = 8294×10^{-4} $\$$

$$K = 8.3 \times 10^{-6}$$

If generator and motors together cost $\$125$ per kwatt = $\$0.125$ per watt

$$g = 0.125$$

$$g/K = \frac{12.5 \times 10^{-2}}{8.3 \times 10^{-6}} = 1.506 \times 10^{4}$$

$$\sqrt{g/K} = 1.227 \times 10^{2} = 123$$

$$\therefore \quad o = 123\,\gamma$$

Broadly the law is :- The maximum economy in outlay is reached when the cost of the wire is equal to the cost of generator plant required in heating the wires.

On Economy in Power Transmission Electric Plants.

Let g = the cost of generators per kwatt ($\$$ per watt)

m = " " motors " " ($\$$ per watts)

$\mathcal{E}$ = " emf of supply at motor terminals. (volts)

γ = " current flowing along line. (amp)

$+$ = " res: per foot of copper employed. (ω)

P = " power delivered at the motor pulley (Watts)

η = " commercial efficiency of the motor at full load

R = " total res: of the line wire ($\frac{1}{2}$ including ground if used)

κ = " copper constant of price.

l = " length of wire (feet)

q = " cost of copper per foot

ρ = " conductivity per foot of copper employed (mhos)

$\mathcal{P} = \frac{\mathcal{E}}{\gamma}\eta$

Emf at generator terminals = $\frac{\mathcal{E}}{\eta} + \gamma R$

Power of generator = $\mathcal{E}\gamma + \gamma^2 R$

Res per foot r = $\frac{R}{l}$

Cost " " = $\frac{\kappa}{r} = \frac{\kappa l}{R}$

Total cost = $\frac{\kappa l^2}{R} = \kappa l r$

Cost of plant = $Pm + \kappa l r + g(\mathcal{E}\gamma + \gamma^2 l r)$ but $\eta = \frac{R}{r}$ $\therefore$ $r = \frac{\eta}{R}$.

$$\frac{dC}{dr} = Pm + \eta l + g(\mathcal{E}\gamma + \gamma^2 l r)$$

$$\frac{dC}{d\eta} = l + \frac{\gamma^2 l}{R}$$

$$\frac{dC}{dr} = -\frac{\kappa l}{r^2} + g\gamma^2 l$$

$$\therefore \quad r = \frac{1}{\gamma}\sqrt{\frac{\kappa}{g}} = \frac{\mathcal{E}\eta}{\mathcal{P}}\sqrt{\frac{\kappa}{g}}$$

The weight of ω c. mil. foot of copper is 3.0×10^{-6} lbs.

cost = $3.015 \times 10^{-6} \times$ cost in $\$$ per lb = $3.015\,c \times 10^{-6}$

ω = $11\,\omega$

for r_ω = $\frac{11}{r}\,c \times 3.015 \times 10^{-6}$ $\$$ per foot

= $\$\ \frac{33.17\,c}{r} 10^{-6}$ per foot.

---

at c = 20 ϕ per lb.

q = $\$\ \frac{6.634}{r} \times 10^{-6}$ per foot.

K = 6.634×10^{-6}

Taking the cost of generators as $\$60$ per kw = $\frac{60.00}{1000} = \$0.06$ per watt.

$$\gamma = \frac{\mathcal{E}\eta}{\mathcal{P}}\sqrt{\frac{6 \times 10^{-2}}{6.634 \times 10^{-6}}} = \sqrt{0.9044 \times 10^{4}} = 0.951 \times 10^{2} \times \frac{\mathcal{E}\eta}{\mathcal{P}}$$

$= \frac{95.1 \times \mathcal{E}\eta}{784,000,000}$ If $\mathcal{E} = 95.1$ = 500,000

$= \frac{500,000}{784,000,000} = \frac{500}{784,000} = \frac{1}{1568}$ "

$= 6.6 \times 10^{-6}$ " per foot

Data and Estimates for the Supply of 1000 H.P. at Julianas Mexico.

1000 H.P. is required to be delivered in distribution by motors.
The distance of transmission from the source of power is 9.5 miles
The source of power is a waterfall.

Assuming that there will be local motors of large size, with a commercial efficiency of 90%, 5% drop in mains and generators of 90% eff: we have following:-

1000 H.P. distributed
1111 H.P. at local motor terminals.
1169.2 H.P. " " generator.
1299 H.P. " motor belt High Tension service. Say 1000 KWTs.

Generating at 5000 volts and loosing 10% on the line = 4500 volts at receiving terminals. 90% eff. = 1111 KWTs. = 2466 amp. say 250.
250 amp. with 500 volt drop = 2Ω res: in the circuit = 1Ω in each line. = 0.1Ω per mile = 580,000 circ: mile: costing at 25¢ per lb. 9280 lbs: per mile - $2320 = 20 miles of line = $46,400.

If the ground could be employed with 400 volt drop in line and 100 volt drop in ground, the res: of the line would have to be $\frac{400}{250}$, 1.6Ω. = 0.16Ω per mile = 362,000 c. mils. 5800 lbs: per mile = $1450 per mile and 10 miles = $14,500.

Allowing $375 an efficiency of 90% in the generator. The power at generator terminals would be 12.50 KWTs = 14.00 KWTs absorbed from the Turbine. In addition to the cost of the Turbine there would be

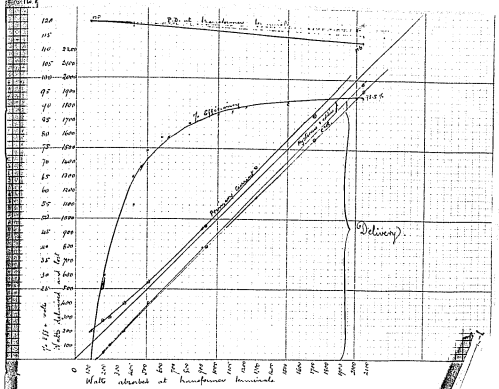
		Ground return
1250 KWTs. dynamo @ $70 per KWT. =	$ 87500	
20 KWTs. exciters	14,500	
	102,000	102,000
Line wire cost of copper	46,400	14,500
	148,400	116,500
1000 KWTs Motors @ $70	70.000	70.000
Exciters	14.500	14.500
	232.900	201.000
1000 KWTs. Generators @ $60	60.000	60.000
	292.900	261,000
750 KWTs. Motors @ $60	45,000	45.000
	337.900	306,000

Assuming that half the power (500 H.P.) could be utilized locally at the receiving station, the remaining 500 H.P. distributed among customers.

500 H.P. distributed
555 H.P. at local motor terminals
584 H.P. " " generator "
650 H.P. " motor belt receiving station
500 H.P. utilized - - - -
1150 H.P. - - - -
1277 H.P. at motor terminals
953 KWTs. " " " = 45,000 volts, 212 amp.

with 425 volts drop = 2Ω res: in the cct. = 0.2Ω per mile = 2850 c mils = 4450 lbs per mile = $1.20 per mile = $11.200 in all.

1060 KWTs. at generator terminals	@ $70	-	$80.00
say 1200 - - -			20.00
30 - exciters			11.200
Single line wire	@ $70		70.000
1000 KWTs. motors motors	$60		30.000
500 - - generators	60		30.000
500 - - Local motors			227.200


P.F. at transformer terminals
% Efficiency
Primary current
Secondary current
Delivery
115 V
Watts absorbed at transformer terminals

Efficiency Test of 2 KWT. Transformer. 15th Oct. 91

Connected transformer up with the dynamometer Wattmeters giving following results

Freq.	τ	Rtr.	α	Primary Watts	Load	Primary C.	Sec. Diff.	Sec. C.	Sec. Watts	Sec. Pd.	Loss
17,400	46.5	713,400	1.435 x10⁻⁶	102.6	0+0	0.2	0	0	0	118	103
16,500	77	1,271,000	"	182.7	1+0	0.27	–	–	80	119	133
17,200	95.5	1,643,000	"	236.3	1+1	0.38	–	–	100	118.5	136
16,800	108	1,880,000	"	271.6	1+1	0.32	–	–	100	118.8	142
17,400	134.5	2,334,000	"	336.5	2+2	0.40	–	–	200	118.3	136.5
16,600	213	3,536,000	"	508.4	4+4	0.55	5.5°	"	400	117.8	108.
16,900	367	6,209,000	"	892.0	8+8	0.93	17°. ?	3.773	899.0	116.3	92.
16,900	349.25	6,634,000	1.298 x10⁻⁶	927.3	8+8	0.95	17°. ?	3.773	800	117.	127.3
17,200	573.5	9,907,000	"	1271.0	12+12	1.37	31°.	5.095	1177	115.5	94.
17,400	693	12,092,000	"	1691.0	16+16	1.80	55°.	6.786	1561	115.0	130.
17,000	861.5	14,710,000	"	2058.0	20+20	–	63.5	8.362	1923	115.0	133.0

Particulars of Transformer as finally prepared for delivery

Length over all = 13 3/4"
Breadth over flange plates = 3 3/16" / 3 7/16"
Depth of box = 3 7/32"
Width " = 3 1/16"
Breadth " core = 3 3/16" 3.15"
Breadth " sides = 2"
Depth " base = 1 7/16"
Rivets = 5/16" countersunk with 0.01" fibre.
Side plates = 1/8"
Weight of iron box = 37 1/2 lbs.
" " lid = 22 .
" " clamps = 6 1/2 .
Primary coil = 12 1/2 . 700 turns of # 16 B+S. 0.064" diam. 40 ohms
Secondary coil = 13 1/2 . 148 " " # 11 B.W.G. 0.120" diam. 0.04 ohms
Total weight of transformer = 93 lbs .
Weight of shell complete = 95 .
Total weight of transformer and shell = 188 lbs .
Res: of primary coil @ 20°C = 3.6 ω @ 83°C = 4.18 ω
" " secondary coil = 0.111 ω each. 0.1375 ω each.
Drop in primary at no load = 0.7 volts at full load = 100°C. 10.4 volts
" " secondary due to pri at load = 1.3 volts } 2.54
" " " to non load = 1.24 " }
Maximum drop in 2ndary = 1.5 volts.
Length of case over all = 17 1/2"
Length of transformer chamber = 14 3/8"
Internal diameter of shell = 10 1/2"
External " " " = 11 3/8" & 12" on flange
Temp recorded on shell = 45°C
" " in inside = 55°C. } after steady full load in 21°C 21°C, 31°C, 56°C.
" " of transformer = 77°C
" " " copper wire = 83°C 62°C

	Balance zero	Tare	Mass	Brake Mass	Driving volts	Friction	% Efficiency	EMF of Mass	Total drop in field coils
1		5 oz 9 dr	0					3.521	0.479
2	50 oz	26	8 2 6	5 oz 6 dr x 10	6.86	3.31		3.439	0.561
3	50	34	12 3 5 / 16 7 5	11 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	8.30	3.70		2.993	0.807
4	50	40	16 2 5 / 12	12 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	7.62	3.4		2.602	0.998
5	50 / 120	16	16 2 5	11 oz 5 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	9.56	4.34		2.574	1.076
6	50 / 120	17	18 2 5	11 oz 6 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	9.40	4.35		2.418	1.140
7	50 / 120	22 / 15	2 1 2 5	13 oz 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	10.45	3.85		2.369	1.181
8	50 / 120	24 / 15	2 2 2 5	13 oz 12 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr 10 dr	10.28	4.32		2.295	1.255

Test of fan-motor with composite frame armature wound for operating a sewing machine with Edison-Lalande battery see p. 108.

The motor dd constructed has 37 turns of # 15 BWG. 0.072" s.c.c. on each half spool or 74 turns x4 - 296 turns all round. Res. of armature @ 20° C between opposite commutator bars = 0.05 Ω.
The series field = 76 turns of # 15 BWG. 0.072" s.c.c. on each spool = 152 turns in all. Res. of field 0.15 Ω. (0.075 Ω on each spool) 4 layer.
The shunt field - 2¼ lbs. of # 23 BWG (equally) divided between spools when 18.67 Ω.
Tested this motor in belt driving small Perrit motor at 5 volts p.d.
Weight with bed-plate 20½ lbs.

No. of Obs.	P.D. at motor terminals volts	Observ.	Current in motor amps	Current calculated in the field	Energy in motor watts	Energy in shunt field	Drop in series field	Energy in field	Brake in grms.	Energy lost in brake	Efficiency	Speed rpm	Speed rps	Current in arm.
1	4.0	0.5	2.607	0.214	10.43		0.359		0.120			700	12.6	2.393
2	4.0	0.58	3.025	0.211	12.1		0.421		0.140		9.67	750	12.5	2.811
3	3.8	0.812	4.235	0.203	16.1		0.605		0.202		12.0	660	11.	4.032
4	3.7	0.995	5.190	0.198	19.2		0.748		0.250		13.0	580	9.67	4.992
5	3.65	1.070	5.580	1.19355	20.37		0.807		0.269		13.9	510	8.5	5.3864
6	3.55	1.130	5.892	0.1902	20.92		0.855		0.285		13.75	488	8.13	5.702
7	3.55	1.170	6.100	"	21.66		0.886		0.295		14.0	465	7.75	5.910
8	3.55	1.2140	6.465	"	22.95		0.941		0.314		14.4	450	7.5	6.275

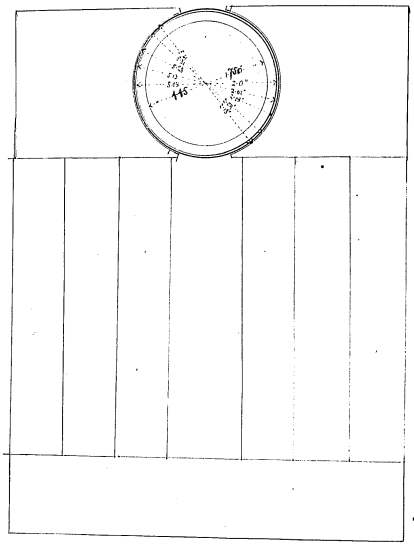
Connected motor with sewing machine Seijen by belt with a velocity ratio 4/7 and took following observations with 10 motor cells lately set up—

No. of Obs.	No. of cells	Observ.	Amp.	P.D. at motor	Energy in motor	Speed of motor	Speed of machine
1	8	1.16		3.55		720	
2	8	1.135		3.70		730	
3	8	1.170		3.50		700	

Data for an Experimental Alternate Current Voltmeter 1000 volt.

The gravity voltmeter whose record is on p. 50 Book IV.
had 202.6 amp. turns on the suspended coil and 6080 on the fixed coil or 8082 in all. With 0.1 amp. there must be 2000 turns on the suspended coil and 8000 on the fixed to produce the same effect.

Full sized section through field magnet and armature.



One layer of # 22 B.W.G. on the armature with covers
4 lbs. 2 oz
12 - - - the field (magnet)

Design for a drum armature motor meter.

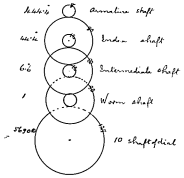
(47)

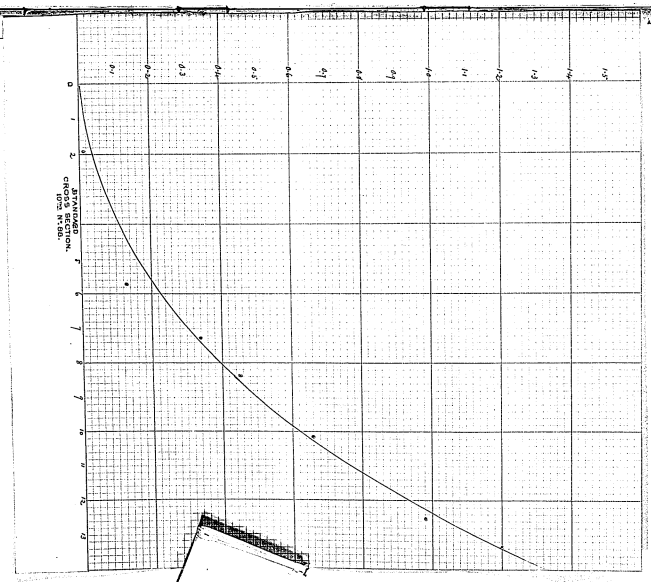
A continuous current drum armature is pivoted upon the lower extremity of its vertical axis.

Diam: of armature body	5.08	2"
Length of body	5.08	2"
Internal diameter	3.83	1.508"
Centre for	0.165	0.066" 1/16
Polar angle	160°	
Polar arc	Thickness	2.93"
Polar area	7.5 × 5 =	37.5 sq: cms say 33 allowing for dispersion at ends
Reluctances of airgap.	0.33/33 =	0.01
MMF for 50,000 lines	=	500 = 400 AT.
Useful cross section iron area	=	3.25 sq: cms.
Diam: of field magnet core	=	2.0 cms = 0.787
Cross section	=	3.14
Diameter of copper wire	=	0.028" # 22 B.W.G. i.e.c. to 0.030"
No. of divs: in commutator	=	20
Thickness of fibre in Rads	=	0.010
Circumference of drum	=	6.28"
- - available	=	6.0"
Number of wires	=	180.
Two wires wound on in parallel.		
No. of effective wires	=	90
Length of one turn	=	0.9'
Total length of wire	=	81'
Total res: of wire	=	81 × 0.01316 ω = 1.066 ω
Effective - -	=	0.0666 ω
Torque $\frac{50,000 \times 1}{10} \times \frac{9}{0.075}$	=	$\frac{3,000,000}{2\pi}$ dyne cms.
	=	47.750 dyne cms = 48 gm: cms.
Maximum speed	=	$10^8/90 \times 50,000 = 10^8/45 \times 10^6$ = 21 = 1260 rpm
Mean turn on core limits	=	0.3'
Total Length of wire	=	120'
- Res: - -	=	0.80 ω = 1200' per ohm = # 12 B.W.G.
	=	0.1067 i.e.c. to 0.138
Four layers of 33 turns on each core.		
Depth of winding	=	0.75"
Weight of field wire	=	4.14 lbs say 4 lbs. 2 oz.

Winding for a 1/10 H.P. slow speed Edison motor for Kinetoscope 7.5 volts.

25 turns of # 21 B.W.G. wire 0.032" i.e.c. to 0.041" in each groove
making 1050 turns on armature.
Speed light on 7.5 volts at m.t. = 23.81 = 1440 rpm
Length of wire on armature = 252' equivalent res: @ 60°C = 0.1 ω
Field wire # 22 B.W.G. 1 lb. x 0.1804 = 2.7 lbs. say 2 lbs. 12 oz.
Current in field 0.5 amp.
Friction probably 12 Watts = 1.5 amp
Total current in machine at no load 2.0 ? approx.


Armature shaft
Index shaft
Intermediate shaft
Worm shaft
10 shaft gear


STANDARD CROSS SECTION. 10'0" R. 1'0".

Tests of Hallenbergen Alternate-Current Meters.

Eight of these meters were connected in simple series and operated at about 10 amp. of effective current from the secondary of a Westinghouse transformer with the following results.

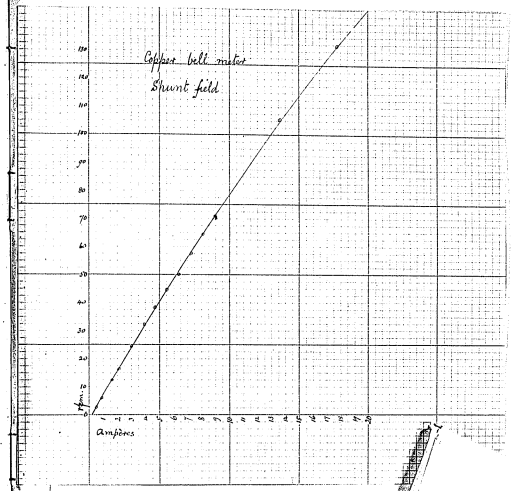
No. of Obs.	Zero	Reading 6th light	Increase	Ratio	Reading 26th light	Total increase	Ratio	Reading 1st Oct.	Total increase	Ratio				
26704	00362	00830	00468	1·031	01051	00689	1·035	02159	01797	1·036				
27025	00258	00712	00454	1·000	00924	00666	1·000	01972	01734	1·000				
27028	00458	00909	00451	0·993	01149	00691	0·993	02195	01737	1·002				
27375	00180	00525	00345	0·936	00728	00528	0·943	01764	01584	0·960				
27486	00360	00800	00440	0·969	01009	00649	0·961	02050	01690	0·975				
27878	00360	00808	00448	0·987	01044	00684	0·997	02072	01712	0·987				
27980	00265	00728	00463	1·020	00943	00678	1·018	02053	01788	1·031				
910	00256	00260	00004	-	00258	00002		00380	-					

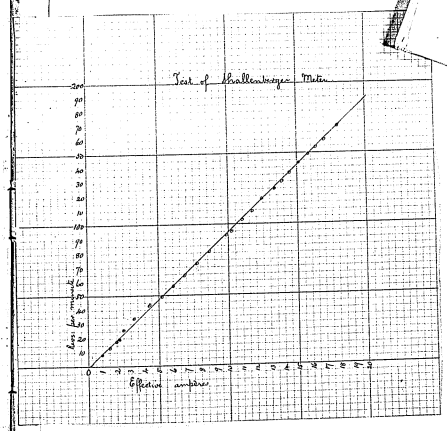
The armature of this motor consists of a corrugated flat plate or shell of metal 3·85 in diam. It carries four vertical fan blades each 2·5 × 5·1 . The shaft has 8 teeth cut into it pinion fashion which operate 80 teeth in a wheel whose axis carries an index finger. The pinion on this shaft has 12 teeth with 80 on the circumference and into the pinion engages a third 80 teeth wheel having a worm on its shaft. The worm wheel has 12·8 teeth and carries the 10 dial shaft so that 12·8 teeth go to one unit so that one ampère hour represents 5690 revolutions, and it has been found that 1 amp. = 9·5 revs. per min. = 570 revs. per hour. The armature is a ring of iron 0·070" deep 0·030" radially mounted on a corrugated aluminium disk. The external distance across fan blades is 11·1 cms. The weight of the fans 7·1
armature 4·5
shaft 4·2
16·8 gms

In order to ascertain how the torque varied with the current, a thread was wound round the shaft and passed over a delicate pulley while the weights (plus and current strengths were observed.

0·058" = 0·2136 cms = 0·1067 cms radius

No. of Obs.	Weights			Total weight	Torque balanced by current	Torque balanced for current	Descending	Ascending	Descending Current	Ascending Current	Mean Current	Torque. Ergs/cm
1	9	0·120	no energy	0·12	-				1·9		1·9 amp	0·0128
2	11	-	energy	1·2	38·5°	38·5°	6·205°	6·205°	5·677	5·677	5·68	0·128
3	17 19	2·0	+	3·2	66·5	68·5	7·517	8·276	6·879	7·573	7·226	0·341
4	29 23	3·0	+	4·2	74·0	94·5°	8·602	9·721	7·872	8·895	8·383	0·448
5	23 27	5·0	+	6·2	105°	144°	10·25	12·0	9·378	10·98	10·679	0·661
6	31 36	8·0	+	9·2	177	200°	13·3	14·14	12·17	12·94	12·56	0·981
7	33 37	10·0	+	11·2	195·5	232°	13·98	15·23	12·79	13·94	13·37	1·195
8	39 45	12·0	+	13·2	256	296·5	16·0	17·21	14·64	15·75	15·20	1·408


Copper ball meter
Shunt field
Volts
Amperes


Test of Wallentaype Meter
Revolutions
Effective amperes

Test of copper bell meter, after the upper cup had been lifted. 119

Oct 22nd

No of Obs.	Time.	Revs.	R.p.m.	R.p.s.	Lamps	Check	amp.				
1	45s.	2	2·6	0·0144	1	0·099	0·51				
2	1m	6·4	6·4	0·1067	2	0·180	0·929				
3	1	12·5	12·5	0·2083	3	0·314	1·620				
4	1	16·6	16·6	0·2766	4	0·408	2·106				
5	1	24	24	0·40	6	0·590	3·045				
6	1	32	32	05·033	8	0·765	3·947				
7	1	38	38	0·633	10	0·911	4·701				
8	1	44·5	44·5	0·7417	12	1·070	5·520				
9	1	50	50	0·833	14	1·220	6·295				
10	1	57·5	57·5	0·958	17	1·400	7·224				
11	1	64	64	1·066	19	1·570	8·100				
12	1	71	71	1·183	21	1·74	8·976				
13	1	105·5	105·5	1·759	31	2·64	13·62				
14	1	132	132	2·2	41	3·42	17·70				

Test of Thullenberger meter # 20704 operated by Edison 2 KWT Transformer making 1140 w or 16800 dc per second minute a glass window over dial into the cover for the purpose of observation (no lit).

No of Obs.	Lamps	Ammeter	Amps.	Time	Revs.	Revs. p min	Revs. per sec.	Secs. per revs	Amp.	Tension degrees	✓
1	1	0·5	0·5						0·465	83 44"	
2	2	1·0	1·0	285.	40	8·418	0·1403	7·125	0·96	17'	2
3	3	1·51	1·51	224·25	50	13·38	0·2230	4·485	1·56	44"	4·123
4	4	1·98	1·98	203·5	60	17688	0·2948	3·392	1·82	61"	6·708
5	5	2·495	2·495	195	30	18·648	0·3158	3·167	2·145	85"	7·81
6	6	2·977	2·977	175	50	26·69	0·4364	2·3	2·5997	1° 7·5	9·22
7	8	3·773	3·773	87·5	50	34·29	0·5714	1·75	2·798	17	2·74
8	10	4·34	4·34	81	50	42·86	0·7143	1·4	4·340	22·5	4·123
9	12	5·22	5·22	67	50	49·39	0·8230	1·215	5·217	32·5	5·701
10	14	6·0	6·0	123·5	100	49·39	0·8330	1·215	5·217	32·5	5·701
11	16	6·85	6·85	106.	100	56·61	0·9434	1·06	6·000	43.	6·557
12	18	7·71	7·71	93·5	100	64·17	1·0695	0·935	6·847	56	7·483
13	20	8·63	8·63	83	100	72·30	1·2048	0·83	7·710	71	8·426
14	22	9·77	9·77	74.	100	81·05	1·351	0·74	8·632	89	9·4234
15	24	10·79	10·79	65	100	92·28	1·538	0·65	9·772	114	10·68
16	26	11·94	11·94	63	100	95·22	1·587	0·63	10·819	124	11·14
17	28	11·68	11·68	116	200	103·45	1·7241	0·58	11·014	145·5	12·06
18	30	12·41	12·41	109·5	200	109·6	1·8266	0·54778	11·68	163	12·77
19	32	13·26	13·26	102	200	117·7	1·961	0·51	12·41	184	13·56
20	34	13·79	13·79	96	200	125·0	2·083	0·48	13·26	210	14·49
21	36	14·38	14·38	92	200	130·5	2·174	0·46	13·79	227	15·07
22	38	15·13	15·13	88	200	136·4	2·273	0·44	14·38	247	15·72
23	40	15·81	15·81	84	200	142·9	2·381	0·42	15·13	273·5	16·535
24	42		16·34	80·5	200	148·9	2·481	0·403	15·81	298·5	17·275
25	44		16·94	78	200	153·9	2·564	0·39	16·34	319	17·86
26	46		17·9	75·5	200	159·0	2·649	0·3775	16·96	343·5	18·53
				73·5	200	169·8	2·797	0·3575	17·9	382·5	19·55

The removal of the cover from the instrument brought the speed down from 168·8 to 111·3 w.p.m. at the last current strength. The drop was 0·6 volt for 17·5 amp.

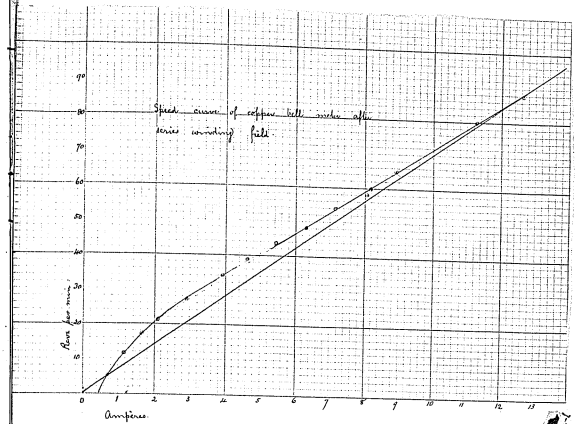
Test of the Magnetic quality of a certain sample bar made from Midgrit steel at 23°

The bar had the following dimensions Length 10·4 Breadth 2·9 Thick. 0·468
Its mass was 161·5 gms. It was magnetized by wedging it lengthways between the poles of the large horseshoe magnet. By the Gauss magnetometer H on the 4th table was found to be 0·1882 the moment of its swing magnet 1439·2 taking its moment of inertia at 287 and its period corrected for torsion at 11·70 seconds. By this the moment of the steel bar was found to be 1295 mean of two distances making a sp mag. of 8·02 and an intensity of 64·3 from which the induction = 809.

The same magnet was hardened glass-hard by very strongly heating and dropping into water. The moment of the bar was then found to be 2364 assuming H = 0·1882. From which I = 11·78 Sp mag = 14·64 Sp mag reduced
A second sample of the same steel measuring 11·1 long 2·85 broad and 0·632 thick, weighing 158·9 gms (x section 1·801 sq. cm.) had a moment of 2660 (with H = 0·1882) and a sp mag. of 16·74 or I = 133·1
The induction through the centre was found by ballistic Galvo.
1·4336 volts 1 ∫ = 1146·7 divs or 1 div = 9·77 × 10⁻¹⁰ abs ∫.
Mean throw from 100 turns of wire moved off or on to the centre of the magnet = 71·8 divs = ∫ = 0·3670 = B 2027 and I from this taking $\frac{B}{H} = 4\pi I$ = 162·2.

This second magnet was heated in a sand bath until its brightened surface showed a red-coloured film. It was then plunged into water, after cooling it was remagnetized. Its moment by magnetometer was 1602 and its intensity 80·1. The induction through the centre was found to be 2110 and the intensity from this $= \frac{B}{4\pi H}$ = 93·2.

No of No.	No. of Magnet	Condition	Assumed H	to cm	Distance of centre	Moment	Dimension of magnet	Sp mag.	I	I by Ballistic Galvo	I by Ballistic Quadrant
1	1	Not hardened	0·1882	0·0507 0·07582	64·5 86·9	1295	11½×2¾×½cm	8·02	64·3		
2	1	glass hard.	"	0·07890 0·07894	68·2 86·2	2364	" " "	14·64	117·3	2027	162·2
3	2	" "	"	0·04733 0·07388	94·0 68·5	2660	11·1×2·85×0·631	16·74	133·1	2027	162·21
4	2	" "	"	0·03533 0·05491	77·4 66·0	1602	"	10·08	80·1	2110	93·2


Speed curve of copper bell wire with series winding field
Revs per min.
Amperes.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
10
20
30
40
50
60
70
80
90

Test of Copper bell meter after series winding.

he winding) consists of 5·5 lbs of #14 B.W.G.
e resistance is @ c producing a drop of volt at 10 amp.
A strong) current – about 20 amperes was first passed through the instrument to overcome any preexisting residual magnetism that might exist in opposition.

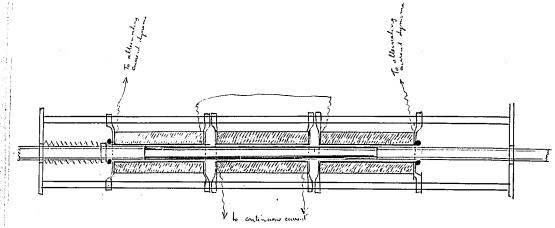
No of Obs	Lamps	Ohms	Amp.	Time	Revs.	Revs per min	Revs per sec.		
1	1	0·110	0·722	60 sec	5·1	5·1	0·085		
2	2	0·225	1·161	"	11·5	11·5	0·192		
3	3	0·315	1·625	"	17·0	17·0	0·283		
4	4	0·406	2·095	"	21·0	21·0	0·35		
5	6	0·565	2·916	"	27	27	0·45		
6	8	0·761	3·926	"	34	34	0·567		
7	10	0·895	4·619	"	39	39	0·65		
8	12	1·05	5·417	"	43·5	43·5	0·725		
9	14	1·22	6·293	"	48	48	0·8		
10	16	1·383	7·134	"	54	54	0·9		
11	18	1·560	8·048	"	58	58	0·966		
12	19	1·580	8·150	"	60	60	1·0		
13	20	1·730	8·924	"	65	65	1·083		
14	25	2·179	11·24	"	80	80	1·333		
15	30	2·650	12·62	"	88	89	1·466		

Data for using permanent magnets with the instrument.

The maximum value of B obtained is 20000 for a steel bar magnet 10 cms long – see preceding page. On a closed magnetic circuit however, the value of B might readily be 8000. In this case to obtain 300000 lines = 37·5 sq. cms = 5·8 sq. ins. = 2·9 sq. ins. on each side and for 200,000 lines 25 sq. cms or 2 sq. ins. on each side.

New Series winding for Sewing Machine Motor.

3 lbs. of #13 B.W.G wire or 1·5 lbs: on each spool and the two cores in parallel. = 0·063 ω each spool @ 20°C or 0·0315 for both together. The length of this will be 10 g' or 542·5' on each spool. = 100 turns or 550 amp. turns at full load.



Record of a test made on an alternating current Rock drill 29th Oct: 91.

A German Patent of Messrs Siemens + Halske # 91469 was received from Messrs Dyer Woolf through Major Eaton. It consists of an iron or soft steel rod or core magnetised by a solenoid carrying a continuous current while two other solenoids one at each end carry alternating currents producing a reciprocating motion of the core. This patent was cited in an interference patent suit between Vandepoele and Marvin, and it was attacked by the former party that the patent was inoperative. A rough model was constructed to ascertain whether it would work.

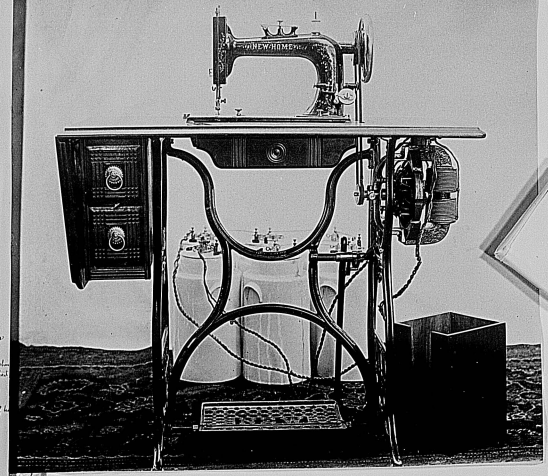
Three air light solenoids about 15 long (6") and 5.5 (2.25") long external diameter were fixed end to end on two guide rods held rigidly in end frame. A length of ½" gas pipe terminated by brass tubes runs freely on rollers through these solenoids. Of these the two outer had 0.185 Ω res. (warm) and had about 250 turns of # 13 B.W.G. The inner or central solenoid was wound with 1.23 Ω (warm) of # 24 B.W.G. This central solenoid was excited by current from the 125 volt mains. (0.3 to 1 amp.). The outer solenoids were operated from the slow speed Edison armatures wound for either alternating or continuous currents in the machine shop, running as an alternating dynamo from a motor by belt.

It was found that with a current in the central coil of about 5 amps the strongest effect in pulses of reciprocation in the rod could be obtained by the use of one alternating coil only. On connecting both alternating solenoids in simple series and in same direction of winding the effect was weak, but it was fairly strong if the solenoids were connected in opposition to each other.

Data and Particulars of Alternating Current Ammeter.

The regular standard Edison gravity ammeter giving a range of 40 with a maximum of 44 amperes was selected and rewound with 38 turns of # 7 B.W.G. in the two layers 25 on the lower and 12 on the outer layer. The length of the solenoid measuring along the axis is 14 cms. (5.5"). The length of the core is 12.5 (5") and diam 0.117" was a sheath of brass 0.005" thick enclosing a bundle of iron wired each 0.01142" # 27 B.W.G. The ends of the axles which are of steel bearing in brass bob 2 cms are 0.039". The weight of the whole ammeter suspension is 20.85 gms. Its c.g. is about 2 cms. below the center of suspension. The radius of the pointer is 14.8 cm and the scale is marked away 5 amps from 0 to 55. The chord from 0 to 50 measures 10.95"

Res: of ammeter = 0.004 Ω. The drop observed was about 0.25 volt at 50 amp Temp. reached by surface of wire in machine after several hours full load 65.5° C or 150° F air 22.2° or 72° F rise 43.5° C or 78° F.


NEW HOME

PARTICULARS AND DATA OF EDISON COMPOSITE FRAME MOTOR
1/30th. HP. BATTERY FAN AND SEWING MACHINE WORK.

This motor is the new Edison composite frame motor of 1/12th. HP. as wound for 120 and 500 volts, with exception of the winding, the base plate, the pulley, and the setting of the grease cups.

Weight of machine complete 20 lbs. (without base 18 lbs. 5 oz.

Armature winding 37 turns of # 15 BWG. 0.072" on each spool.

Total number of turns round armature 296.

Total length of wire on armature about 104 feet.

Number of commutator bars 16. Diameter of commutator 1"

Diameter of pulley 1.375" in groove, 1.78" edge.

Width of pulley 1/2"

Weight of wire on armature about 1 lb. 10 oz.

[illegible] 1.5 lbs. of # 18 BWG on each spool

[illegible] on each spool in 6 layers of 10

[illegible] the motor 4 lbs. 10 oz.

[illegible] temperature of 20°C.

[illegible] brushes and connections

[illegible] field spools in parallel

[illegible] of motor between terminals

[illegible] field about 100 feet or 50 on each spool.

[illegible] motor inverted, or with its base [illegible]

[illegible] under surface of the sewing machine table. Grease

[illegible] opposite position to that they occupy in

[illegible] directly to driven pulley

[illegible] the motor is [illegible]

[illegible]

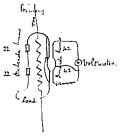
Particulars and Data of Sewing Machine motor as finally tested and prepared for shipment.

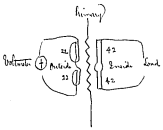
Weight of motor without bed plate 18 lbs: 5 oz.
" " armature wire 1 lbs. 10 oz.
" " field wire 3 lbs.
Total weight of copper on motor = 4 lbs. 10 oz.
Armature winding 37 turns of # 15 B.W.G. wire 0.072" on each spool
Total number of turns on armature 296.
" length " wire " " 104 feet
Number of commutator bars #. 16
Diameter of commutator 1".
" " pulley 1.325" in groove 1.78" on edge
Field winding 90 turns of # 13 B.W.G. 0.095" d.c.c. & 0.109".
Two spools in parallel. 6 layers of 15 turns on each. , 180 turns in all.
Diameter of core 1.5"
" over winding 2.7"
Diameter of mean turn 2.1"
Mean circumference 6.6" = 0.55'
Length of wire on each spool 49.50'
Res: of armature (@ 20°c. 0.057 ω
" field (in parallel) 0.032 ω
" brush connections 0.022 ω
" " motor 0.11 ω

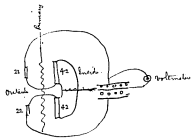
Test of motor fitted to sewing Machine (New Home Type) Speed 1.8. — 60 amp: cells

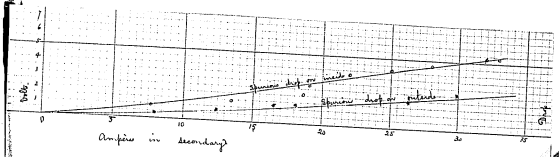
No. of Cells	EMF of battery	EMF for all	P.D. at M.T.	Drop.	Res. of battery circuit	Speed of motor	Speed of Sewing mch	Efficiency	Amps.	Energy in motor Watts	Total Energy lost in motor	Energy utilised
6	4.36	0.727	3.3	1.86	0.239	900	500	0.86	4.44	14.65	7.2	7.45
6	4.36	0.73	3.1	1.26		800	4444	0.89	4.59	14.26	7.3	6.96
7	5.10	0.73	3.7	1.40	0.280	864	480	0.97	5.006	18.5	7.75	10.75
8	5.85	0.730	4.3	1.55	0.310	936	520	1.06	5.47	23.5	8.32	15.18
8	5.85	0.730	4.45	1.40	0.327	"	"	0.83	4.283	19.1	7.0	12.0
8	5.85	0.73	1.8	4.05	0.257	—	held	3.05	15.75	29.9	—	—

The torque of the motor is about 7 lbs. weight at a radius of 1.33" = 3175 gms. = 3.38 cms.
with a current of 13.21 amps. = 10730 cm-gms.
Produced by 6 cells of battery. = 812 cm-gms. per amp.


Primary
Voltmeter
Load


Primary
Voltmeter
Load


Primary
Voltmeter
Load

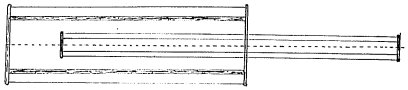

Volts
Amperes in secondary
Apparent drop for inside
Apparent drop for outside

Particulars of Tests with 80-light Transformer.

The electrical design of this transformer appears on page 111.
It was found that with the winding there given 142 double wires could be slot wound on the inside and 22 double turns outside the primary, no room for being found for the 20 turns 1½ layer necessary to complete the design. The transformer now weighs 130·5 lbs.
The res. of the primary is 2·01 ω @ 20°C.
" " " secondary " 0·078 ω " " (two coils in series)
The drop in this transformer was observed in three ways:-

No. of Obs.	Condition	Deprs.	✓	Current	Drop.	Assumed Pri. e.s.	Pri. Drop	Sec. of Drop	Total Sec. drop	Specific drop
1		6·6	2·569	7·75	$\frac{116\cdot7}{108\cdot5}$ = 1·2	1·0	2	0·25		0·95
2		20	4·4472	13·5	$\frac{116}{120\cdot3}$ = 1·8	1·7	3·4	0·4		1·4
3		38	6·164	18·6	$\frac{117\cdot3}{113\cdot7}$ = 2·7	2·3	4·6	0·6		2·1
4		40	6·325	19·1	$\frac{118\cdot3}{111\cdot3}$ = 3·9	2·4	4·7	0·6		3·3
5		52	7·211	21·75	$\frac{115\cdot4}{111}$ = 4·4	2·7	5·4	0·7		3·7
6		69	8·307	25·03	$\frac{116\cdot9}{111}$ = 5	3·1	6·2	0·8		4·2
7		87·5	9·3524	28·2	$\frac{116}{110\cdot2}$ = 5·5	3·5	7·0	0·9		4·6
8		112	10·583	31·9	$\frac{116\cdot3}{116}$ = 6·3	4·0	8·0	1·0		5·3
9		118·5	10·880	32·8	$\frac{116\cdot5}{108\cdot3}$ = 8·0	4·1	8·2	1·0		7·0
10		7"	2·646	7·98	$\frac{116\cdot3}{116\cdot3}$ = 0·5	1·0	2·0	0·1		0·4
11		17"	4·123	12·43	$\frac{117\cdot9}{117\cdot3}$ = 0·9	1·5	3·0	0·2		0·7
12		30"	5·477	16·51	$\frac{117\cdot7}{116\cdot2}$ = 1·5	2·1	4·2	0·25		1·25
13		36·	6·	18·1	$\frac{117\cdot5}{115\cdot5}$ = 1·6	2·3	4·6	0·3		1·3
14		76·2	8·729	26·32	$\frac{117\cdot2}{116\cdot9}$ = 2·3	3·4	6·8	0·4		1·9
15		97·9	9·896	29·83	$\frac{116\cdot8}{113\cdot8}$ = 3·0	3·7	7·4	0·4		2·6
16		115·0	10·7238	32·35	$\frac{115\cdot4}{112\cdot3}$ = 2·8	4·0	8·0	0·5		2·3
17		171·5	13·09	39·47	$\frac{116\cdot4}{112\cdot3}$ = 3·3	5·0	10·0	0·6		2·7
18		202·0	14·21	42·85	$\frac{116\cdot5}{113\cdot7}$ = 3·5	5·4	10·8	0·7		2·8
19		238·0	15·43	46·53	$\frac{118\cdot4}{113\cdot4}$ = 3·5	5·8	11·6	0·7		2·8
20		10"	3·162	9·53	$\frac{84}{84}$ = 1	2·4	4·8	0·6		0·4
21		22"	4·690	14·15	$\frac{84}{77}$ = 2	3·6	7·2	0·9		1·1
22		46"	6·782	20·45	$\frac{84}{84}$ = 3	5·1	10·2	1·3		1·7
23		87·5"	9·354	28·2	$\frac{84}{84}$ = 7	7·0	14·0	1·75		5·25
24		101"	10·20	30·75	$\frac{84}{84}$ = 7	7·8	15·6	1·95		5·0
25		135·5	11·63	35·07	$\frac{84}{84}$ = 9	8·75	17·5	2·2		6·8
26		146	12·08	36·42	$\frac{84}{84}$ = 9	9·10	18·3	2·3		6·7
27										

Full sized sectional section of coils.



0·36 lbs of wire exp 0·42 lbs (6⅔%) of covered wire # 33 B.W.G. in 14 layers of 340 turns coil on outer coil wound.
4 layers of same wire on inner Coil wound.

Res. of Weston Voltmeter 20550 } Multiplying power 5·857
" " 10,000 ohm box 9,980
" " field resist. 1st coil 215
" " 2nd " 215·5
" " armature as 320 ω.
" " motor = 753·5 ω

No. of Obs	P.D. on motor terms	Strength in field	Amps.	Strength in armature	Calculated Ω on armature	Deflection	B.M.F.	Speed of armature r.p.m.	r.p.s.	Watts for armature	Energy lost in field watts	Energy lost in armature watts	Efficiency watts
1	531·3	0·10657	0·0801	314·7	296·6	25·7	470·9	2091	34·85	13·51	2·79	2·1	37·8
2	524·14	0·13906	0·1048	455·4	479·0	33·5	465·5	1801	30·0	14·85	4·76	3·5	46·7
3	522·6	0·15926	0·1205	522·2	470·4	38·6	431·8	1661	27·7	15·57	6·3	4·7	52·1
4	529·0	0·17633	0·133	577·7	471·3	42·6	428·7	1605	26·8	16·0	7·7	5·7	57·
5	532·0	0·20345	0·1534	665·5	465·5	49·1	411·4	1512	25·2	16·5	10·2	7·5	63·9
6	537·7	0·2217	0·1671	724·4	465·3	53·5	411·8	1465	24·4	16·88	12·1	8·9	68·8
7	538·9	0·24945	0·1127	488·9	490·0	36·1	453·9	1520	25·3	17·94	5·5	4·1	51·2
8	543·	0·25662	0·1980	864·5	458·5	62·4	396·1	1280	21·3	18·6.	16·5	12·3	77·3
9	533·	0·1238	0·0926	402·2	492·8	29·6	463·2	2125	35·4	13·08	3·7	2·7	43·0
10	534	0·24621	0·2333	996·8	437·2	71·4	465·8	1241	20·7	22·8	21·6	16	81·4

After operating motor for four hours on the last load — delivering about 446 Watts. The temp. on the armature was 93° F. air 60°. = 23° F
28° C. " 15·5 = 12·5 C.

Res. when hot armature 328 ω. Field 452, Motor 780 ω.

PARTICULARS OF WINDING ON EDISON COMPOSITE FRAME 1/12HP.
MOTOR FOR 500 VOLT CIRCUITS. NOV. 1891.

Weight of machine on base complete 20 lbs. 6 oz.

Armature winding 2700 turns on each spool of # 33 BWG. wire 0.008" d.s. covered to 0.011"

Total number of turns on armature 21,600.

Field winding 1 1/4 lbs. of # 31 BWG. 0.010" d.s.covd.

Resistance of armature - cool (20 C) 300 ohms.

Resistance of field - Series 420 ohms.

Total resistance of motor at 20 C. 720 ohms.

Commutator bars and winding divisions 32.

Speed without fan 2000 revs. per min.

Speed with fan 1600 revs. per min.

Current taken by motor running without fan 0.08 ampere.

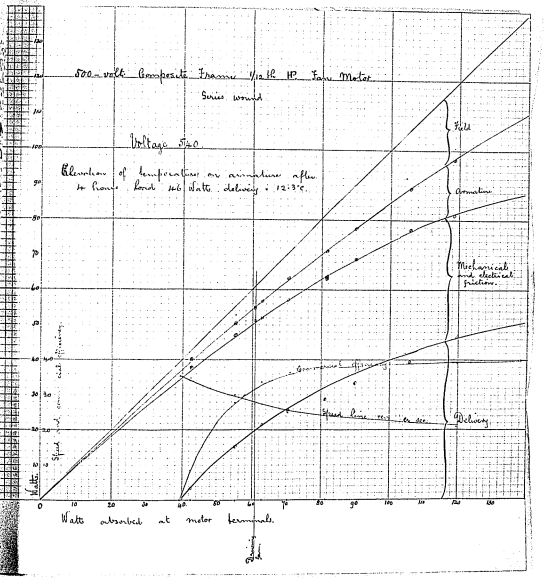
Current taken when driving fan 0.11 ampere. 55 watts. energy

Elevation of temperature on armature after delivery of 46 watts at shaft during four hours - 12.5 C.

Commercial efficiency 40%

Delivery of motor at full load 50 watts.

Delivery of motor running fan 20 watts.


500-volt Compositè Frame 1/12 H.P. Fan Motor.
Series wound
Voltage 500
Efficiency of temperature on armature after
2 hours' test 106 Watts delivery = 12·3 C.
Field
Armature
Mechanical and electrical friction.
Speed in revs. per sec.
Watts absorbed at motor terminals.

Calculation of the winding for a gravity-voltmeter intended for alternating currents.

External and fixed solenoid 7in.3 sq. cms. of surface
Allowing 30 sq. cms. per watt and 1/10 W. amp. = 250 m.

External dia. 2.7 area 5.73
Internal " 2.0 " 3.142 annulus area 2.61 sq. cms.
Length 8.6. Volume of winding 22.45 sq. cms.

$0.0392 \sqrt[4]{\frac{23.65}{350}}$. $0.0392 \sqrt[4]{68.95}$ $= 0.0392 \sqrt[4]{8.98 \times 10^{-2}}$

$= 0.0392 \sqrt[4]{3.796 \times 10^{-1}}$

$= 0.0392 \sqrt{2.796 \times 10^{-2}}$

$= 0.0392 \times 5.474 \times 10^{-1}$

$= 2.1146 \times 10^{-2} = 0.02$

$= 0.0193$ cm $= 0.0076$".

This is #32 B.W.G. nearest size 0.008" = 0.010" silk covered.
250 m. of this wire = 1550 feet. = 6000 turns, and 340 turns per layer
= 18 layers = 0.18" depth of winding.
200 m. of this wire = 1240 feet = 4960 " and 340 turns per layer
= 14 layers = 0.14" depth of winding. = 500 amp. turns.
Four layer of same wire on inner solenoid 475 turns per layer
= 1900 turns = 124 feet. = 20 m. and 190 amp. turns.
Total power 690 amp. turns.

Test of 500-volt Motor 1/12 H.P. composite Frame non sf

The motor whose winding is mentioned on p. 101 and whose field and armature frames were received from Schenectady was planted in bank and coupled with the Perot Motor 1/4 H.P.

Balance no.	Moment	616.5 × Moment ×10⁻⁷	Energy deficient	Friction	Energy in watts	Power efficiency	Work done	
50	3.3	165	10017	3.54	34.2	42.7	0.083	Driving Part armature
	16.5	825	1.509	15.27	31.4	55.0	0.278	" " Pole field
	25	1250	0.770	21.33	30.7	63.0	0.339	" " 1 lamp
	31	1550	0.957	25.62	31.4	70.4	0.364	" " 2 "
	37	1850	1.140	28.7	35.2	81.6	0.352	" " 4 "
	44.5	2225	1.372	33.5	35.3	89.8	0.373	" " 6 "
	18	900	0.555	14.1	37.1	60.8	0.232	" " Series field in Pole field
	60	3000	1.85	39.14	37.8	105.9	0.372	Driving Part + 6 lamps
	0	-	-	-	43.0	49.14	0	Light + Idle
50	72	3600	2.25	46.6	314.8	119.3	0.390	6 lamps + Part

Data of winding. 24000 turns on each spool = 48,000 turns on the armature of #33 B.W.G. 0.008" d.s. covered to 0.011"
Field winding 1½ lbs of #31 B.W.G. 0.010".

Weight complete with cover & on base 20lbs 6 oz.

$\frac{3.25}{0.0292} = 55.84$ $\log_{10} = 1.74695 \times 2.3026 \times 4.022 \times 2 = 8.044$ $\frac{1}{8.044} = \text{anti}\log 0.12493 \times 0.1781 =$

0.0224 ℓ per mile.

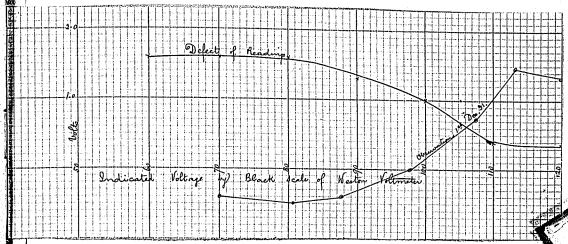
$\frac{0.45}{0.0403} = 11.2$ $\log_{\epsilon} = 2.4159 \times 2 = 4.832$ $\frac{1}{4.832} = 0.2069 \times 0.1781 = 0.037$ ℓ per mile

This would probably (0.037 ℓ) be the capacity with unit sp. ind. cap.

so that $\frac{0.085}{0.037} = 2.3$ is the highest sp. in. cap. permissible.

$\frac{0.45}{0.0329} = 12.54$ $\log_{\epsilon} = 2.5278 \times 2 = 6.4696$ $\frac{1}{6.4696} = 0.15456 \times 0.1781 = 0.0277$ ℓ per mile

$\frac{0.075}{0.0277} = 2.7$ is in this case the dielectric constant.



Recalibration of Weston alternating and continuous Current Voltmeter 11th November 91.

The instrument was upset and slightly damaged owing to the rigid attachment of its cords. Its attachment plugs were altered to prevent a recurrence of the accident, and the instrument recalibrated. The following readings were then obtained by potentiometer, using a bridge to subdivide the pressure.

No. of Obs.	Potentiometer Reading	Ratio	Voltage	Voltage indicated by Weston Voltmeter	Error of Voltmeter
1	0.603	200 : 1	120.6	120.25	0.35 low
2	0.575	"	115.0	115	0
3	0.552	"	110.4	110	0.4 low
4	0.505	"	101.0	100	1 "
5	0.456	"	91.2	89.9	1.3 "
6	0.41	"	82	80.4	1.6 "
7	0.361	"	72.2	70.6	1.6 "
8	0.308	"	61.6	60	1.6 "
9	0.501	100 : 1	50.1 Red	50.18 on Red scale	—

On the Capacities specified for by the Chicago and American Bell Telephone companies in their cables per mile.

The Chicago Co:

800 pair cables. Each wire #18 B+S. 0.0403".
98% cond: not to exceed 36ω per mile @ 60°F = 15.5°C.
It should be observed that 5280' of this wire if of Matthiessen's standard @ 20°C should have a res: of 3356ω as that at 20°C 93.2% conductivity is allowed.
Each wire insulated by a diam: of at least 0.1".
Core kept up in twisted pairs with an outside covering not less than 0.02".
Outside diam: 2¼", enclosed in pipe whose outside diams 2½".
Average static capacity, one wire against all others + sheath 0.085μf per mile
Maximum " " " " " " " 0.090μf " "
Insulation 100 Ω per mile. @ 60°F (15.5°C)

The American Bell Co:

52 pair cables. Each wire #19 B+S 0.0359".
98% cond: not to exceed 46ω per mile @ 60°F (15.5°C)
5280' of this wire have @ 0.00800ω per ft = 42.27 ω so that @ 20°C 91.9% cond: is allowed.
Capacity not to exceed 0.080μf per mile, nor to average over 0.075μf per mile, all measured against all the others and the sheath.
Insulation 100Ω per mile @ 60°F when connected + ready for use measured any one wire against all others and sheath.

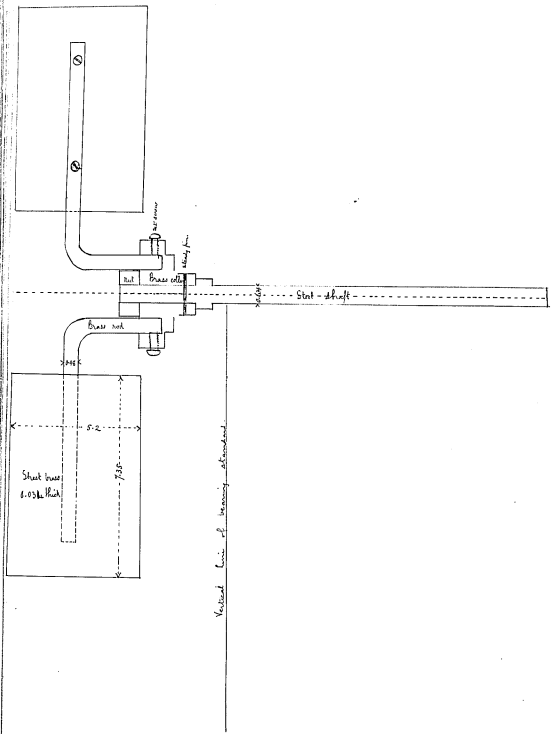
12403 × 0.1711 :

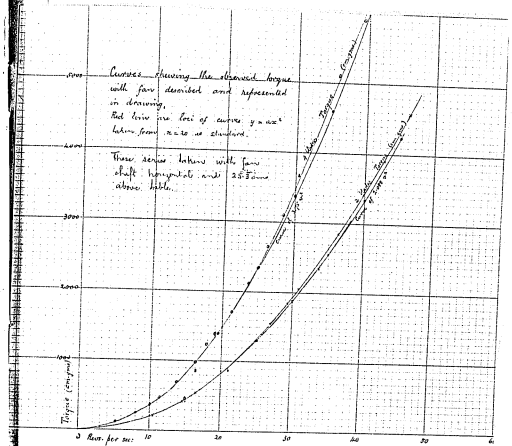
0.027 μf per mile

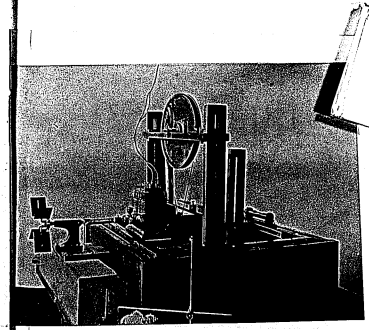
ofs ind: cap:

0.0277 μf per mile

Full sized axial section of fan carrying four blades.




Curves showing the observed torque with fan described and represented in drawing.
Red lines are loci of curves $y = ax^2$ taken from $x = 0$ to standard.
Three series taken with fans shaft horizontal and 2½ diameters above table.
Torque in grammes
Revs. per sec.
Curve of Torque = 1.2 (revs)²
Curve of Torque = 1.5 (revs)²



Dimensions and Data of a brass Experimental Fan.

Weight of the fans and shaft 2.33 gms.
The blades are flat rectangular sheets of brass, whose planes can be set at any desirable angle with the shafts axis, but the fan blades planes one another must be parallel to the axis and cannot be adjusted helically to it.

In these experiments the fan was coupled to a Perot motor of ¼ H.P. through a flexible spring and the motor mounted in the small floating dynamometer.

No. of Obs	Speed of Countershaft in R.P.M.	Speed of Fan in R.P.M.	Belt Drive	Moment in Gms.	Energy	Speed of Countershaft	Speed of Fan in R.P.M.	Balance used	Moment in Gms.	Energy
1	32	5·2	50 on 2·5	12·5	0·1401	64	10·44	50 on 1·3	215	1·1345
2	449·5	8·04	" 5·0	250	1·239	90	14·63	" 2·5	425	2·265
3	760·0	11·38	" 9·5	475	3·344	101·5	16·5	" 11·0	550	3·731
4	824	13·65	" 14	700	5·892	129·5	21·05	" 17·5	875	5·939
5	101	16·41	" 19·3	965	8·752	165	26·80	" 31·0	1550	9·1338
6	1097·5	17·8	" 24·75	1238	13·89	170·5	29·33	" 37	1850	11·41
7	1119·5	19·142	" 28	1400	16·76	189·5	30·80	" 44	2200	13·84
8	1130·5	21·21	" 34·2	1710	22·36	207	33·69	50 on 7·3	2465	16·58
9	1445·5	23·64	" 42·3	2115	30·93	223·5	36·3	50 on 11·5	2850	19·77
10	1615·5	26·24	50 on 13 / 100 on 20	2650	42·88	265·5	39·9	100 on 20·5 / 100 on 20	3465	24·02
11	1755	28·43	50 on 22 / 100 on 20	3100	54·35	283·5	42·8	50 on 22 / 50 on 20	3900	27·05
12	1888	30·55	100 on 32·5 / 50 on 20	3675	(eq·22	282·0	46·15	100 on 11·5 / 50 on 20	4375	3·321
13	2011	32·66	100 on 32·5 / 50 on 20	4175	84·06					
14	2221	35·92	100 on 20 / 200 on 20	5100	113·0					
15	2442	39·33	200 on 36 / 200 on 20	5700	143·1					
16	2794·5	45·42	50 on 0·8	20	0·2561	1·12				
17	3500·0	56·88	50 on 1·6	40	0·1403	2·80				

$$\int_0^{2\pi} d\theta = 2\pi$$

$$\int_0^{2\pi} \cos\theta \, d\theta = 0$$

$$\int \left(\frac{3}{2}\cos^2\theta - \frac{1}{2}\right) d\theta = \frac{3}{2}\int_0^{2\pi} \cos^2\theta \, d\theta - \frac{1}{2}\int_0^{2\pi} d\theta$$

$$\frac{3}{2}\int_0^{2\pi} \cos^2\theta \, d\theta = \frac{3}{2}\cdot\frac{1}{2}\left[\sin\theta\cos\theta + \theta\right]_0^{2\pi} = \frac{3}{4}\cdot 2\pi = \frac{3\pi}{2}$$

$$\frac{1}{2}\int_0^{2\pi} d\theta = \pi \quad \pi$$

$$\int_0^{2\pi} \left(\frac{5}{2}\cos^2\theta - \frac{3}{2}\theta\right) d\theta = \frac{5}{2}\int_0^{2\pi} \cos^2\theta \, d\theta - \frac{3}{2}\int_0^{2\pi} \theta \, d\theta$$

$$\frac{5}{2}\int_0^{2\pi} \cos^2\theta \, d\theta = \frac{5}{2}\left[\sin\theta\left(\frac{1}{3}\cos^2\theta + \frac{2}{3}\right)\right]_0^{2\pi} = 0$$

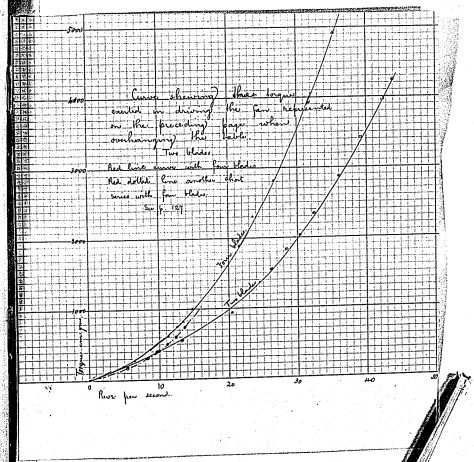
$$-\frac{3}{2}\int_0^{2\pi} \cos\theta \, d\theta = -\frac{3}{2}\left[\sin\theta\right]_0^{2\pi} = -\frac{3}{4}\cdot 0\pi^2 = 0$$

$$\int_0^{2\pi} \left(\frac{27}{256}\cos^4\theta - \frac{3\cdot 5}{2\cdot 4}2\cos^2\theta + \frac{1\cdot 3}{2\cdot 4}\right) d\theta = \frac{27}{256}\int_0^{2\pi} \cos^4\theta \, d\theta - \frac{2\cdot 5}{4}\int_0^{2\pi} \cos^2\theta \, d\theta + \frac{1\cdot 3}{2\cdot 4}\int_0^{2\pi} d\theta$$

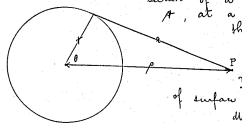
$$\frac{5\cdot 7}{2\cdot 4}\int_0^{2\pi} \cos^4\theta \, d\theta = \frac{5\cdot 7}{2\cdot 4}\left[\sin\theta\left(\frac{1}{4}\cos^3\theta + \frac{3}{8}\cos\theta\right)\right]_0^{2\pi} + \frac{5\cdot 7}{2\cdot 4}\cdot\frac{3}{8}\theta\Big]_0^{2\pi} = 0 + \frac{3\cdot 5\cdot 7}{2\cdot 4\cdot 8}\cdot 2\pi$$

$$-\frac{3\cdot 5}{4}\int_0^{2\pi} \cos^2\theta \, d\theta = -\frac{3\cdot 5}{4}\left[\frac{1}{2}\sin\theta\cos\theta + \frac{1}{2}\theta\right]_0^{2\pi} = -\frac{3\cdot 5}{4}\pi$$

$$\frac{1\cdot 3}{2\cdot 4}\int_0^{2\pi} d\theta = \frac{1\cdot 3}{4}\pi$$


Curve showing Water Tongue
exerted on driving Pipe from which the
on Pipe preceding Gauge values
overhanging Pipe Heads
Two blades
Red Line same with four blades
Red dotted Line another shape
same with four blades
See p. 169
Water Tongue
Revs per second.

To determine the potential of a thin cylindrical section of a uniform surface density with radius A, at a point P in its plane distant ρ from the centre of the cylinder.



Let q be the charge on the cylinder per unit of length.

Then the potential dV due to an element of surface $r\,d\theta\,dy$ is

$$dV = \frac{q\,dy}{2\pi}\frac{d\theta}{} \cdot \frac{1}{2}$$

$$= \frac{q\,dy\,d\theta}{2\pi}\left(r^2+\rho^2-2r\rho\cos\theta\right)^{-\frac{1}{2}}$$

$$= \frac{q\,dy\,d\theta}{2\pi\rho}\left(1+a^2-2a\cos\theta\right)^{-\frac{1}{2}}$$

$$\therefore V = \frac{q\,dy}{2\pi\rho}\int_0^{2\pi}\left(1+a^2-2a\cos\theta\right)^{-\frac{1}{2}}d\theta$$

Expanding this in a converging series of spherical harmonics;—

$$V = \frac{q\,dy}{2\pi\rho}\left[\int_0^{2\pi}d\theta + a\int_0^{2\pi}\cos\theta\,d\theta + a^2\int_0^{2\pi}\left(\tfrac{3}{2}\cos^2\theta-\tfrac{1}{2}\right)d\theta + a^3\int_0^{2\pi}\left(\tfrac{5}{2}\cos^3\theta-\tfrac{3}{2}\cos\theta\right)d\theta + a^4\int_0^{2\pi}P_4\cos\theta\,d\theta\right]$$

$$= \frac{q\,dy}{2\pi\rho}\left[2\pi + a\cdot 0 + a^2\left(0+\tfrac{2}{2}\pi\right) + a^3\left(0\right) + a^4\left(\tfrac{3\cdot5\cdot7}{2\cdot4}\pi - \tfrac{3\cdot5}{2\cdot4}\pi + \tfrac{3}{4}\pi\right)\right]$$

$$= \frac{q\,dy}{2\pi\rho}\left\{2\pi + a^2\left(\tfrac{2}{2}\pi\right) + a^4\pi\left(\tfrac{3\cdot5\cdot7}{2\cdot4\cdot8} - \tfrac{3\cdot5}{2\cdot4} + \tfrac{1\cdot3}{2\cdot4}\right) + \right\}$$

$$= \frac{q\,dy}{\rho}\left\{1 + \frac{a^2}{4} + a^4\frac{7}{64} + \right.$$

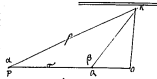
$$= \frac{q\,dy}{\rho}\left\{1 + \left(\tfrac{r}{\rho}\right)^2 + \left(\tfrac{7}{8}\tfrac{r^4}{\rho^4}\right)^2 + \right. \qquad \text{where } a = r/\rho.$$

Continuation of Fan experiments. Nov. 12th 91.
Fan overhanging? table on this occasion 2-blades only

No. of Obs.	Speed of Countershaft r.p.m.	Speed of Fan r.p.m.	Balance	Moment	Moment × 6165	Energy Watts
					$\times 10^6$	
1	61	9·912	50 @ 8	400	0·2466	1·505
2	81·5	13·25	" 11	550	0·3392	2·765
3	98·5	16·01	" 11·8	590	0·3638	5·823
4	127	20·64	" 18·8	940	0·5797	11·96
5	161	26·16	" 31·1	1550	0·9555	24·99
6	175	28·43	" 36·5	1825	1·125	31·98
7	186·5	30·31	" 40·6	2030	1·252	37·95
8	199·5	32·42	50 @ 6·6 100 @ 20·	2330	1·437	46·57
9	221·5	35·99	20 @ 87·4 100 @ 20	2870	1·770	63·71
10	240·5	39·09	50 @ 20·1 100 @ 20	3405	2·10	82·06
11	261·5	42·5	200 @ 20	3965	2·445	103·9
12	270	43·85	200 @ 20	4282	2·641	114·7

Velocity ratio of shafting 9·75 ÷ 60 · 0·6625

Electrical Images by the Quaternion Method.



To prove that the locus of the positions in space for which $\frac{\alpha}{T\rho} + \frac{\beta}{T(\rho-\sigma)} = 0$ is a spherical surface where α and β are scalar quantities with opposite signs.

$\therefore \frac{\alpha}{T\rho} = \frac{\beta}{T(\rho-\sigma)}$ as quantities

or $\rho^2 = \frac{\alpha^2}{\beta^2}(\rho^2 + \sigma^2 - 2S\rho\sigma)$

or $\rho^2 = \frac{\alpha^2}{\beta^2-\alpha^2}(\sigma^2 - 2S\rho\sigma)$ (1)

Let To $\frac{\alpha\beta}{\alpha^2-\beta^2} = p$ $\therefore \rho^2 = T\rho\left(\frac{\alpha^2}{\alpha^2-\beta^2}\rho^2\right)\left(1 - \frac{\alpha^2}{\alpha^2-\beta^2}\right)$

$(\rho - m\sigma)^2 = -p^2$ the equation of a sphere

Equation (1) becomes

if $m = \frac{\alpha^2}{\alpha^2-\beta^2}$ $\therefore OA = \frac{\beta^2}{\alpha^2-\beta^2}PA$

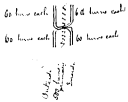
$OR = PA\frac{\alpha\beta}{\alpha^2-\beta^2}$

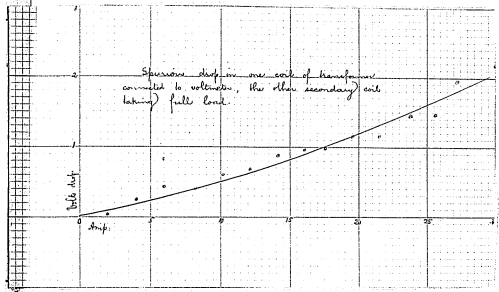
Fan experiments continued : Nov. 16th 91.

Four blades on fan overhanging edge of table.

No. of Ht.	Speed of Countershaft	Speed of fan rpm.	f. p.s.	Balance	Moment	6lbs Moment	Work.	
1	34	331.6	5.527	50 @ 25	175			
2	50	487.6	8.127	" 6.0	300			
3	59	575.3	9.590	" 8.0	400			
4	68	663.0	11.05	" 10.0	500			
5	76	741.0	12.35	" 12.0	600			
6	84	819.0	13.65	" 14.7	735			
7	40	390.	6.50	" 5.5	275			
8	53	516.7	8.611	" 8.7	435			
9	64.25	675.2	11.25	" 12.2	610			
10	77	750.5	12.512	" 15.0	750			
11	82.25	802.1	13.37	" 16.5	825			
12	91	887.3	14.79	" 20	1000			
13	132	1288.	21.467	" 37.5	1875			
14	144.5	1409	23.484	50 @ 46 100 @ 20	2300			
15	164	1599	26.65	50 @ 41.5 100 @ 20	2825			
16	195.5	1907	31.79	50 @ 38.5 100 @ 20	3925			
17	217	2116	35.27	50 @ 18 200 @ 22	4900			
18	239	2331	38.87	50 @ 37.5 200 @ 26	5875			

For the graph of these observations see the curve sheet on the preceding page.





If c_2 is the current in the sec.

$\frac{c_2 \times 6}{25} + 0.35$ is the approx primary cr

$1.3\left(\frac{6}{25}c_2 + 0.35\right)$ - - - - drop

$1.3\left(\frac{6}{25}c_2 + 0.35\right)\frac{8}{25} + c_2 \times 0.036$ . . secondary .

$= c_2\left\{\frac{(8\times13)}{625} + 0.036\right\} + \frac{5.2\times0.35}{25}$

$= c_2(0.0374 + 0.036)$

$= c_2(0.0734) + 0.05$

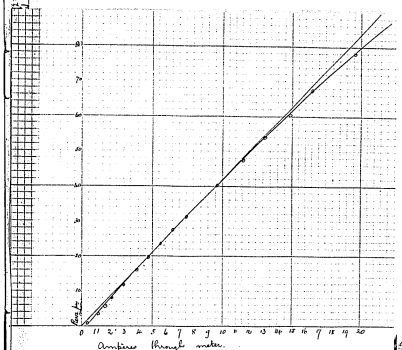
Test of 80-lt. transformer after first modification.

The same wire was employed, but the number of turns was altered. The primary was reduced to 500 and the secondaries to 60 double turns each. The resistance of the 30 inside double turns = 0.015Ω and of the 30 outside turns 0.021Ω making a total of 0.036Ω each half secondary or 0.072Ω for the complete secondary of 2440 volts. The exciting current is now 0.36 amp. Res. of primary = 0.31Ω.

No. of Obs.	Pr. Current	Pr. drop.	Sec. drop due to Pr. drop	$\frac{A}{B}$	Sec. degrees	√	A amp.	Sec. drop observed	Sec. drop due to Ir.	Total secondary drop due to Ir. & Cr.	Sp. inductive drop.
	0.36	0.117									
1	0.274	0.71	0.095	5	5°	2.236	2.026	0.274	0.074	0.16	0.011
2	0.76	0.996	0.12	10	19.5°	4.359	3.989	116.5 / 116 = 0.5	0.1144	0.26	0.214
3	1.00	1.31	0.157	15	44°	6.633	6.069	116.8 / 116 = 0.8	0.219	0.38	0.442
4	1.27	1.663	0.20	20	82.5°	9.082	8.310	116.8 / 116.1 = 0.9	0.3	0.5	0.4
5	1.55	2.03	0.2444	25	127°	11.27	10.31	117.3 / 116.1 = 1.2	0.37	0.61	0.57
6	1.80	2.358	0.283	30	181°	13.45	12.31	117.3 / 116.1 = 1.2	0.444	0.72	0.68
7	2.044	2.672	0.321	35	240.0	15.49	14.17	116.8 / 115.1 = 1.7	0.51	0.83	0.87
8	2.28	2.987	0.357	40	308°	17.55	16.06	116.6 / 114.6 = 1.9	0.58	0.94	0.96
9	2.46	3.222	0.387	45	34°	5.83	17.58	117.0 / 115.0 = 2.0	0.63	1.02	0.98
10	2.75	3.602	0.432	50	42.5°	6.52	19.66	117.3 / 114.9 = 2.3	0.71	1.14	1.16
11	2.94	3.852	0.46	55	57°	7.14	21.53	117.3 / 114.9 = 2.4	0.78	1.24	1.26
12	3.21	4.205	0.505	60	62°	7.874	23.75	117.2 / 114.2 = 2.5	0.86	1.37	1.43
13	3.40	4.453	0.535	65	72.5°	8.515	25.68	116.6 / 113.6 = 2.7	0.93	1.47	1.43
14	3.63	4.755	0.570	70	82°	9.055	27.30	116.0 / 112.5 = 3.5	0.98	1.55	1.95
15	3.70	4.847	0.582	75	91°	9.539	28.77	115.5 / 111.7 = 3.8	1.036	1.62	2.18
16	4.0	5.240	0.629	80	103.5°	10.173	30.68	114.2 / 109.1 = 4.5	1.105	1.73	2.77

Connected Transformer up on regular 3-wire connection taking one side to voltmeter and ammeter. Observed following series.

No. of Obs.	Load A side	Load B side	Degrees on A side	√	Current in B amp.	Volts on Load A	Volts on A side	Drop on A side.	Calculated drop	Sp. inductive drop
1	5 Lamps	5 Lamps	5°	2.236	2.026	119.	118.8	0.2	0.15	0.05
2	10 "	10 "	21.5°	4.637	4.243	119	118.5	0.5	0.3	0.2
3	15	15	47	6.856	6.278	119.5	118.0	1.5	0.5	1.0
4	20	20	82	9.055	8.286	119	117.	2.0	0.6	1.4
5	25	25	131	11.445	10.47	121	119.8	2.2	0.8	1.4
6	30	30	180	13.416	12.275	119.5	116.2	3.3	0.9	2.4
7	35	35	236	15.362	14.06	118.5	114.5	4.0	1.0	3.0
8	41	39	275	16.583	15.18	119.5	114.0	4.5	1.1	3.4
9	~~44~~	37	252	15.874	14.53	119.1	116.9	4.2	1.1	3.1


Amperes through meter.

Test of Copper Bell Meter with Permanent Magnets.

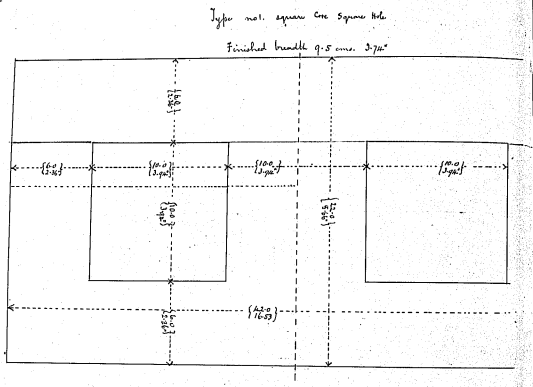
Four steel bar magnets each 1·30 × 3·8' were laced in place and wound temporarily with wire. They were then magnetised by passing a strong current through the wire while striking them with a mallet. The winding was then removed.

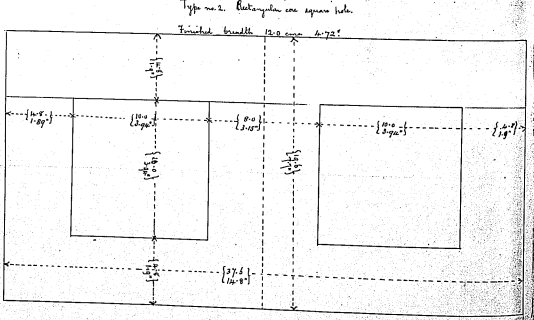
The following observations were then made:—

No. of Obs.	Lamps	Oh. m.	Amps.	Time	Revs.	Mean Flow per rev.	Mean Revs per min.		
1	1	0·089	0·1427	65 sec.	1	65·0	0·92		
2	2	0·235	1·213	88	5	17·6	3·41		
3	3	0·331	1·708	10m	10	10·0	5·77		
4	4	0·422	2·178	75·5 / 75·5	10 / 10	7·55	7·95		
5	6	0·593	3·061	61·8 / 60·8	10 / 10	6·08	11·81		
6	8	0·758	3·912	38·6 / 38·8	10 / 10	3·8	15·79		
7	10	0·913	4·712	31·8 / 30·0 / 31·7	10 / 10 / 10	3·17	18·93		
8	12	1·109	5·625	1' 23·5 / 1' 16·0 / 1' 7·0	5 / 5 / 5		23·5		
9	14	1·265	6·526	1 / 1	27 / 82·0		27·4		
10	16	1·450	7·482	1 / 1	31·5 / 62·5 / 94·0		31·3		
11	20	1·870	9·648	1 / 1	24·75 / 1·20·5		140·2		
12	24	2·24	11·56	1 / 1	42·0 / 116·0 / 158·0		47·6		
13	28	2·53	13·06	1 / 1	52·0 / 104·0 / 156·0		52·0		
14	32	2·870	14·81	1 / 1	60·5 / 121·0 / 181·5		60·5		
15	36	3·20	16·51	1 / 1	67·5 / 134·5 / 201·5		67·2		
16	44	3·790	19·56	1 / 1	78·0 / 234·0 / 234·0		78·0		
17									

Repetition of test next day (18th Nov)

No. of Obs	Lamps.	Oh. m.	Amps	Time	Revs.	Mean Time per rev.	Mean Flow per min.		
1	1	0·084	0·433	1 m.	0·5 ?				
2	2	0·184	0·970	123 sec.	5'	24·6 sec.	2·44.		
3	3	0·326	1·683	103·5	10·0	10·35	5·69.		
4	4	0·427	2·284	3m.	23·1	7·	7·7		
5	6	0·600	3·297	3m.	34·4		11·47		
6	9	0·850	4·387	3m.	51·1		17·0		
7	12	1·122	5·790	3m.	69·0		23·0		
8	16	1·450	7·2180	3m.	93·0		31·0		





Strip 7/8" x 0.020" = 24 BWG or # 22 B&S.
7/8" x 0.

PARTICULARS AND DATA OF EDISON MODEL 5 KILOWATT TRANSFORMER.

Primary effective voltage 1000.
Secondary effective voltage at no load 120 volts [illegible] 240
Primary exciting current 0.45 ampere.
Primary current at full load 5.5 amperes.
Secondary current at full load 21 amperes.
Primary winding 400 turns of # 12 B&S. 0.105" dec. [illegible]
Secondary winding 96 turns of doubled strip in two coils one above and one below the primary, each coil consisting of 48 turns of doubled strip. Strip 7/8" wide and 0.020"
Weight of primary coil 43 lbs. 14 layers.
Weight of secondary coils 29 lbs. in all, 14.5 lbs. each.
Resistance of primary coil at 20 C. 0.792 ohm. 1.021 at 100 C.
Resistance of secondary 0.032 ohm each coil at 20 C. or 0.041 ohm in series 0.0425 ohm at 100 C.
Drop in primary at full load (1000.) 5.57 volts or 0.47 volt in secondary single coils.
Drop in secondary at full load (1000) 0.47 volt.
Total secondary drop at full load due to resistance [illegible] volts
Extra drop due to leakage 4.0 volts at full load.
Total secondary drop at full load 5.5 volts (120- 114.5)
Total weight of iron in box lid and side pieces 140 lbs.
Iron plates 0.011" Dimensions:-
Length 16.54" Breadth 6.3"
Core breadth 3.88" Breadth of grooves 3.94"
Breadth of base and of walls 2.36"
Lid 10.4" long 2.4" broad.
Breadth of transformer across plates 3.75"
Six rivets in box and three in lid, each 3/8", holes 23/64"
Sleeves of fiber over rivets as insulators.
Thickness of side plates 1/4"
Surfaces in contact of box and lid planed true.
Total weight of transformer without shell 198 lbs.
Weight of shell 114 lbs.
Total weight of transformer complete in shell 310 lbs.
Outside dimensions of shell 21" x 14 1/2" x 12 3/4" high.
Total surface of shell sheet 2490 sq. cm.
Temperature elevation of transformer after 24 hrs. load 35° C.
Temperature elevation of iron core after 24 hrs. full load 30° C.
Shell nearly approaches its maximum temperature elevation after 4 hours full load.
Loss of power in transformer at no load 230 watts.
Loss at full load 300 watts. Efficiency 0.943
Total weight of copper in transformer 62 lbs.

Design for a 100-Light or 5000 Watt S. Transformer.

Primary effective voltage	=	1000 volts.
Secondary " "	=	120 - 3-wire at no load.
Primary exciting current	=	0.4 amps
Primary current at full load	=	5.4 -
Secondary " " "	=	21 -
Primary winding	=	400 turns. of # 12 B.W.G. 0.109" d.c.c. & 0.122"
Secondary "	=	(96/96) double turns of # 9 B.W.G. 0.148" d.c.c. & 0.162" brought out at the 48th double turn for neutral.
Length of mean turn	=	30 cms = 2.622' type I and 31 cms = 2.66' in type II.
" " primary winding	=	400 × 2.64' = 1056' = 32000 cms.
" " secondary "	=	96 × 2.64' = 253.5' = 7730 cms. (doubled)
Weight of primary	=	1056' @ 0.036 = 38.0 lbs.
" " secondary	=	2 × 253.5' @ 0.0664 = 33.7 -
Total weight of copper	=	71.7 lbs.
Loss in primary	=	0.9175 @ 20°C = 1.05 @ 60°C = 1.18 @ 100°C.
" " secondary	=	0.060 @ 20°C = 0.0688 @ 60°C = 0.077 @ 100°C.
Drop in primary at load	=	6.37 volt = 0.76 volt in each secondary.
" " secondary "	=	0.8 volt. @ 100°C. - -
Total drop in secondary	=	1.56 - @ 100°C. due to resistance.
Mean length of mag. ckt.	=	60 cms. in type I and 56 cms. in type II
Gross section of central core	=	100 × 9.5 = 95 sq. cms. × 0.93 = 88.4 sq. cms. in type I 80 × 12.5 = 100 - × 0.93 = 93.3 - - - II
" " rest of core	=	12.5 × 9.5 = 119 - × 0.93 = 106 - - - I 12.5 × 10 = 125 - × 0.93 = 107 - - - II
Assumed value of ϕ	=	380,000 C.G.S. 397,000
Maximum value of B	=	3770. 4440 and therefore 3.746
Area of air gaps	=	95 over centre and 112 over sides.
Winding space section	=	10 × 10 or 100 sq. cms. = 15.5 sq. ins.
M/A of magnetic circuit	=	10/10 + 20/12 = 1 + 1.16 = 2.16/19 = 0.114 in type I 10/8 + 56/9.6 = 1.25 + 5.8 = 0.857/12 = 0.82 - II
Space occupied by primary	=	400 × 0.0145 = 5.8 sq. ins.
" " " secondary	=	192 × 0.0262 = 5.04
Total space occupied	=	10.84 -
Coefficient allowed for ins:	=	1.43.
Surface of iron on one side	=	42 × 22 − 200 = 724 in type I. ∴ 37.6 × 19.6 − 200 = 537 in II
" " " top	=	42 × 9.5 = 399 - - + 37.6 × 12.0 = 451 - -
" " " sides	=	22 × 9.5 = 209 - - + 19.6 × 12.0 = 235 - -
Total surface of iron	=	= 2664 sq. ins. - - + -21.46 - -
Volume " "	=	724 × 9.5 = 6883 c.c. - - 537 × 12.0 = 6444 c.c.
Mass @ 7.8	=	53670 gms. = 118.3 lbs. - I @ 50270 gms = 111 lbs. -

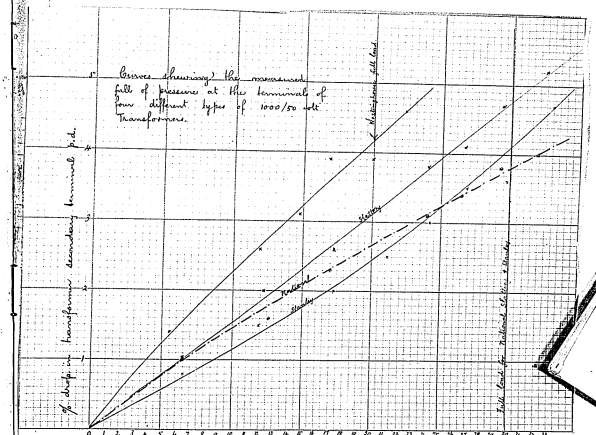
Weight of transformer without shell type I. Iron 118. lbs.
Rivet and joint plate 8. -
Iron 126. - @ 0.05 = $6.30 $0.06 per lb.
Copper 71.7 - @ 0.20 = 14.34 0.113 -
197.7 - 20.64 = 0.206 per lb.

Primary loss of energy at full load 35 Watts
Secondary " " " " 314 -
Hysteresis " " " 230 300 Watts. 5000/5300 = 0.944 efficiency.

The cross section of the secondary conductor is 0.0242 × 2 = 0.0484 sq. ins = 0.0312 sq. cms.
Allowing 3.94 × 0.90 − 0.125 = 3.415" as the breadth of primary coil, there would be 28 layers and consequently the turns in each layer are 14 = 1.87" + 0.13" = .20" thick.
This leaves 1.94" in depth of winding space = 0.2 = 1.74" available and if the strip be 0.75" wide it must be 0.058" thick. Allowing for insulation of tape = 0.0850" between = 0.142" and 48 of such strips = 3.38".
Taking 0.875" wide ÷ 2 = 0.4375" = 7/16" the thickness = 0.0393" + tape = 0.058"
48 such thicknesses = 2.78 ins.

Four rolls of copper band 7/16" × 0.0393" or 4 rolls 7/16" × 0.0200
23 Brs. = 0.02257"
One foot of 0.02000 × 0.875 = 0.219 Cub ins = 0.00886 lbs. = 0.1420 lbs. = 3.51 lbs.

$\frac{1.4414 \times 10^{11}}{4 \times 5900 \cdot 2 \times 10^{5}} = \frac{1.4414 \times 10^{7}}{35.616} = 397,000$


Curves shewing the commencing fall of pressure at the terminals of four different types of 1000/50 volt Transformers.
% drop in transformer secondary terminal p.d.
Effective amperes in secondary circuit (lamps in use and dynamometer)
Full load current in secondary circuit
Full load p.d. at secondary terminals

Magnetic Test of Copper Bell Meter 19th Nov.

The bell were prevented from running by adding weights to a fibre carriage held by a fine silk thread running rounds the shaft just below the worm and then over a delicate pulley. The torques was then measured at several successive current strengths as follows—

No of Obs.	Rad of shaft	Weight of carriage	Weights on carriage	Total weight	Obsvtn	Amp.	Torque cent. gms	Torque per amp.	Means Torque per amp.
1	0·257	1·17	10 gms.	11.17	0·415	2·14	2·87	1·34	
2			20	21.17	0·770	3·97	5·44	1·37	
3			30	31.17	1·170	6·035	8·01	1·33	1·340
4			40	41.17	1·42	7·326	10·58	1·444	
5			50	51.17	1·70	8·77	13·15	1·50	
								4)8	

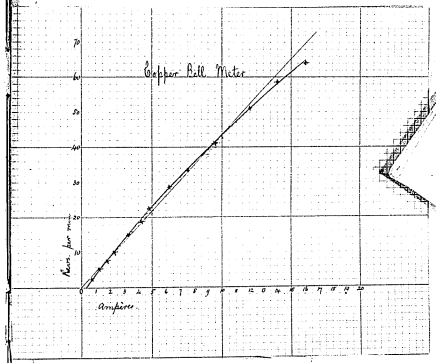
1·340 cm. gms = 1·340 × 981 = 1314 dyne-cent. per amp. = 13140 per c.g.s. unit of current = 86,314.0 c.g.s. lines through the bell.

Comparison of the load drop in four transformers 20th Nov. 91.

The transformers were 1 of 4 Westinghouse for 20 lights (50 volts)
1 Slattery 30 lights (50 volts)
1 National 30 " "
1 Stanley 30 " "

These were successively operated on a bank of 60 volt lamps with a voltameter and Siemens dynamometer in the circuit.

Load	Transformer	Dynes	I	Amp.	Volts at load off	Volts at terminals load on	Drop	% Drop
9d	Westinghouse	36·5	6·076	5·53	50	49.3	0·7	1·4
20		170	13·014	11·93	50·2	48·9	1·3	2·6
25		258	16·06	14·7	50·0	48·65	1·35	2·7
30		337·7	18·36	16·8	50·0	48·05	1·95	3·9
35		423	6·56	19·78	49.65	47·7	1·95	3·9
40		524	7·34	23·28	49·6	47·3	2·3	4·6
10	Slattery	51	7·141	6·53	52·90	52·5	0·5	1·0
20		193	13·89	12·71	52·78	50·78	1·0	2·0
27		355	18·84	17·24	51·95	50·65	1·3	2·6
40		62.	7·874	23·78	51·65	49·75	1·9	3·8
45		78	8·83	26·64	51·7	49·65	2·05	4·1
50		95	9·75	29.40	51·6	49.15	2·35	4·7
55		116	10·77	32·47	51·6	49.0	2·60	5·2
10	National	50	7·07	6·147	52·45	52·05	0·5	1·0
20		191	13·82	12·64	51·25	50·25	0·8	1·6
27		343	18·52	16·93	50·15	50	1·15	2·3
40		63	7·94	23·95	51·25	49·5	1·75	3·1
45		77·5	8·80	26·58	51·0	49·3	1·7	3·4
50		94	9·70	29·25	51·0	49·1	1·9	3·8
55		112	10·58	31·90	50·5	48·5	2·0	4·0
10	Stanley	51	7·14	6·53	51·25	50·95	0·4	0·8
20		183	13·53	12·38	51·0	50·25	0·75	1·5
28		356	18·87	17·26	51·0	50·0	1·0	2·0
35		449	7·00	21·1	51·15	49.9	1·25	2·5
40		614	8·00	24·15	51·14	49·9	1·5	3·0
45		79	8·89	26·81	51·25	49·5	1·75	3·5
50		96	9·85	29·70	51·14	49·6	1·5	3·6
55		114·5	10·93	32·95	51·9	49·85	2·35	4·7


Copper Bill Meter
Revs. per min.
Amphères.

Magnetic Test of Copper Bell Meter after balancing. 20th Nov.

The bell was found to be slightly out of balance. It was checked and bolted home with a slightly enlarged shaft (0.525 diam.) When reset, the following observations were made:-

Ref No.	Rad. of shaft	Weight of carriage	Weight added	Total weight & effect	Obsvd.	Amps	Torque cm's gms.	Torque per ampere cm's gms.	Mean Torque per ampere
1	0.2625	1.17	10	11.17	0.415	2.142	2.932	1.369	
2			20	21.17	0.770	3.974	5.557	1.398	
3			30	31.17	1.150	5.933	8.182	1.379	1.391
4			40	41.17	1.525	7.968	10.81	1.381	
5			50	51.17	1.826	9.420	13.43	1.426	

The mean torque of 1.391 cm's gms per ampere = 13.91 per 1 E.M.U current
= 13,650 dyne cms representing a useful flux of 85,740 C.G.S. lines.

Speed Test of Copper Bell Meter after balancing. 21st Nov.

The speed of revolution was observed for different strengths of current in the usual way:

No. of Obs.	Lamps	Obsvd.	Amp.	Time	Revs.	Mean time per rev:	Mean revs per minute	
1	1	0.145	0.748	min. sec. 2.1 / 2.1 / 2.1	1 / 1 / 1	2.1	2.857	
2	2	0.225	1.265	10.7	10	10.7	5.61	
3	3	0.340	1.755	7.6	7.6 / 7.5 / 7.8	7	7.7	
4	4	0.431	2.240	5.9	10 / 10 / 10		10.1	
5	6	0.632	3.262	3.3	14.8 / 14.8 / 14.5		14.0	
6	8	0.808	4.170	3.3	20.2 / 20.2 / 19.8		18.8	
7	10	0.951	4.910	3.3	22.5 / 22.5 / 23.5		22.5	
8	13	1.20	6.193	3.3	28.6 / 28.6 / 28.2		28.4	
9	16	1.45	7.48	3.3	33.5 / 33.0 / 34.0		33.16	
10	20	1.827	9.428	3.3	41.0 / 41.0 / 41.0		41.0	
11	25	2.330	12.02	3.3	51.0 / 51.0 / 51.0		51.0	
12	30	2.71	13.99	3.3	59.0 / 59.0 / 59.5		58.8	
13	35	3.15	16.26	3.3	66.0 / 63.0 / 63		64.0	

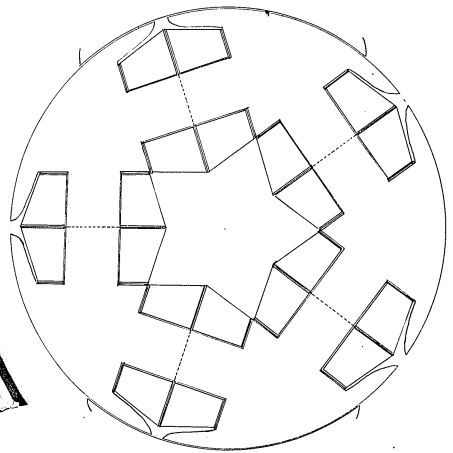
The instrument as at present adjusted makes 4.3 revs per min: for one ampere as an average speed. = 258 revs per hour per amp. Each 5 revs of the shaft give 1 on the dial and consequently a new gear wheel has to be introduced making 52 : 1

The pressure at terminals of the instrument was found to be 0.016 volt with 20 lamps and Obsvd 1.68 in circuit = 8.67 ℓ. = 0.00184 ω. Scarcely any change was detected on open circuiting or reclosing the armatures. With 30 lamps + Obsvd 2.75 = 14.2 amps p.d. = 0.028 volt res: 0.00197 ω.

Full sized section of armature 125 Watt Motor in plane of revolution through centres of coils.

The armature was subsequently made hexagonal see Book VI

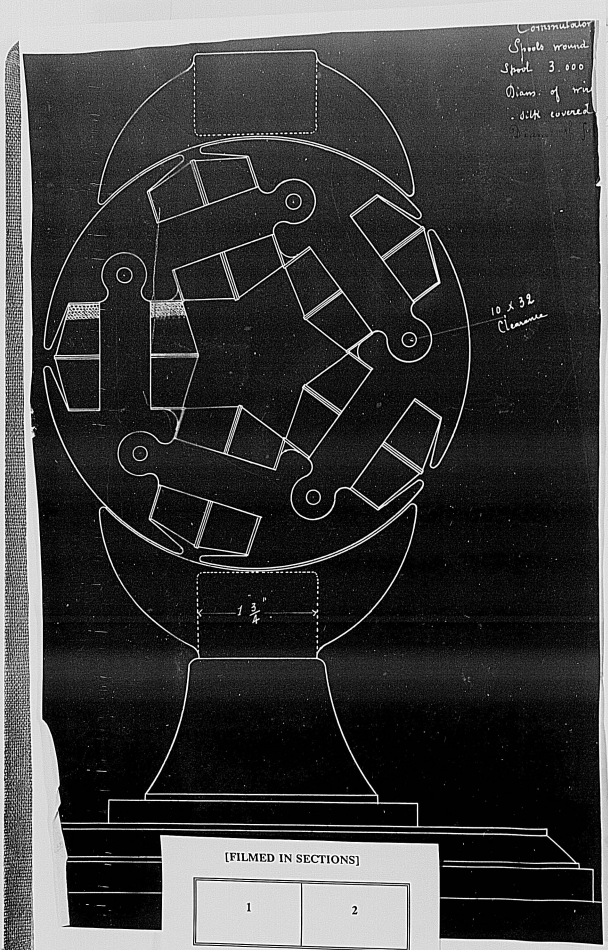
Armature 20 plates broad each 0.0375"
= 0.75" aggregate width.



120 volt winding.

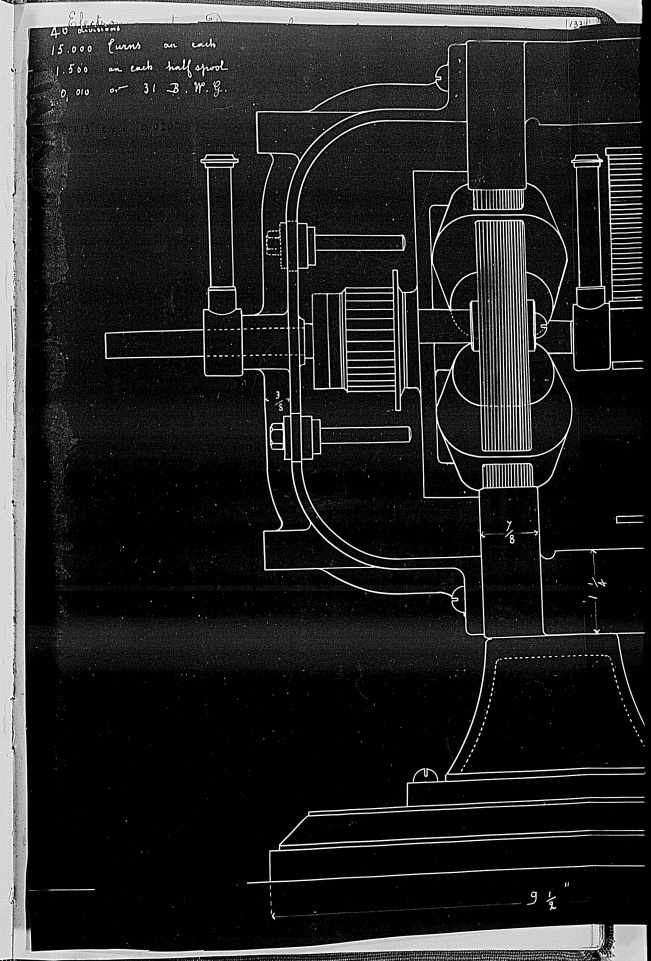
Speed without load = 1800 rpm or 30 per second

Turns needed on armature	=	3200. 160 on each double spool .320 on each weight spool
Section allowed per turn	=	8.75×10^{-4} sq. in.
Diameter of wire	=	2.958×10^{-2} = 0.030" or 0.022" # 22 B&S s.c.c.
Weight of wire on armature	=	0.22 lb on each half spool 0.345 lb on each spool 2.07 lb on armature.
Length " "	=	137' on each half spool 275' on each spool 1650' on armature.
Res: " " cool 20°	=	2.06 ω " " 27.3 " " 164 ω " between
" " warmed	=	3.9 ω " " 51.8 " " 311 ω " "
Number of commutator bars	=	28
Current at full load	=	1.6 amp.
Drop in armature	=	11.8 volts cool 12.6 volts warm.
Field winding	=	2 lbs. of # 22 B&S 0.028" s.c.c. & 0.035".
Length of wire	=	840'
Nos of turns	=	1300 (650 on each spool)
Amps / turns at no load	=	340 ?
" " full "	=	2040.
Res. of winding	=	11 ω cool 12.7 ω warm
Drop in " at load	=	17.6 volts " 20.3 volts "
Total drop in machine	=	29.6 " " 33.9 " "



[FILMED IN SECTIONS]

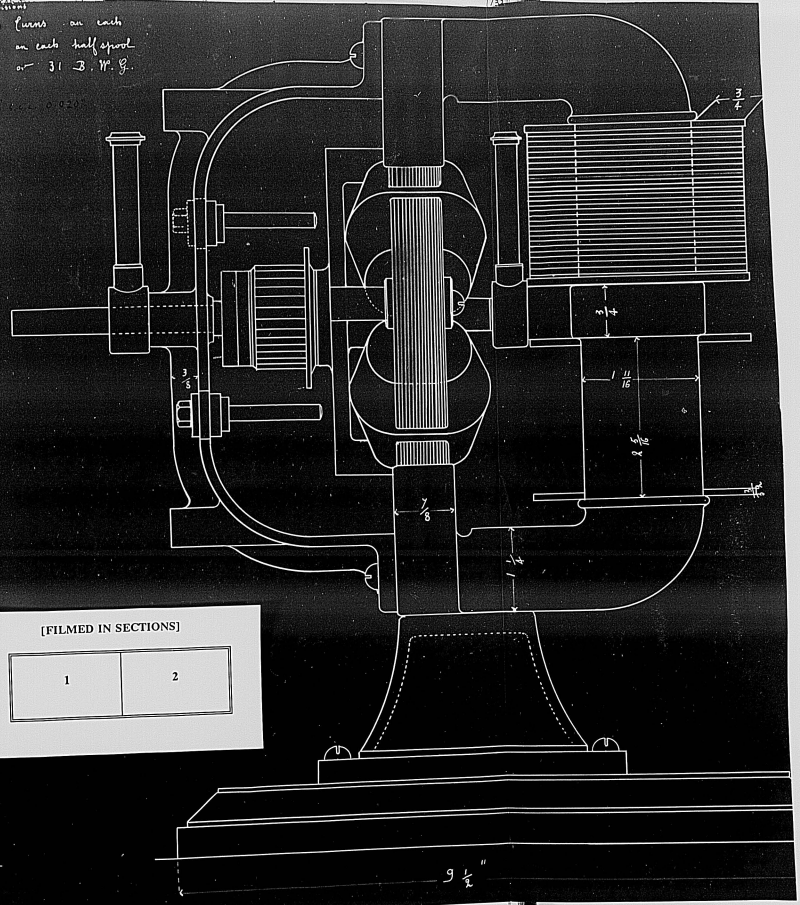
1	2



Commutator
Spools wound
Spool 3.000
Diam. of wire
- disk covered

10 x 32
Clearance

40 Sections
15.000 Turns on each
1.500 on each half spool
0.010 of 31 B. W. G.



[FILMED IN SECTIONS]

1	2

...motor in plane

Elec

C
D

...s ... 1/8 HP. ... 0.125 (HP)
...Brake Test ... Watts and Amperes for 125 and ...
... Blocked, still ... motor in gear with two spools.
... Sensitive Sensor in fra e, non-rotative.
... 115 volt model 1500 r.p.m. weight 140 at fan load
... 200 " " 1800 " 1.70 " "
... of motor without fan ... base 23 lbs.
Armature winding 125-volt model 3600 turns of # 24 BWG.
0.025" s.c.c. to 0.032" 600 turns on each spool.
Weight of armature wire 2 lbs.
Resistance of armature 6.4 ohms between brushes at 18 C.
7.1 after one hour's full load.
Field winding 125-volt 2 lbs. of # 32 BWG. 0.028" s.c.c. to 0
13 layers of 53 turns on each spool or 689 turns on
each spool, 1378 turns in all.
Resistance of field spools 9.9 ohms at 18 C., 11.8 ohms
after one hour's full load.
Total resistance of 125-volt model 16.4 ohms cool, 18.9 hot
Total weight of copper in model 4 lbs.
Armature winding 500-volt model 16,500 turns of # 31 BWG.
0.010" d.c.c. to 0.015" 2750 turns on each spool.
Weight of armature wire 2 lbs.
Resistance of armature between brushes 149 ohms cool
... ohms after one hours load.
... winding 500-volt 2 lbs. of # 28 BWG. 0.013" s.c.c.
to 0.020" 39 1/2 layers of 120 turns on each spool
making 3540 turns on one spool or 7080 on both.
Resistance of field winding 277 ohms a 18.0 or 308 ohms
after one hour's full load.
Total resistance of 500-volt model 436 ohms cool, 469 ohms ht
Total weight of copper on model 4 lbs.
Commutator 24 bars 125-volt. 36 bars 500-volt.
Energy absorbed by motors running light 50 watts.
Delivery of 125-volt model 129 watts at intake of 300,
or full load efficiency of 42.7 %. Maximum efficiency
48 % at 2/3rds. output.
Delivery of motor at fan load, about 60 watts.
Armature plates. 0.059" thick 21 plates in breadth, 126 in all
Cross section of armature core 0.75" X 0.75"
Weight of iron in armature 4 lbs.
Maximum current that can pass through motor on circuit if
deliberately arrested 7.5 amperes in 125-volt, and
1.14 ampere in 500-volt motor.
Temperature elevation of hottest part of motors after one
hour's full load:- 125-volt 25 C., 500-volt 17 C.

Electromagnetic Design for a slow-speed Composite Frame Armature 500 = volt Series Motor. 20th Nov. 91.

Power	=	1/6 Hr. HP or 12.5 Watts, at least in 120 volt size delivered at shaft.
Voltage	=	500, capable of being wounds for lower pressures.
Field commercial eff at full load	=	0.5
Current at full load	=	0.5 amp. @ 500 volts.
Useful armature flux	=	120,000
Speed at load	=	1500 r.p.m. = 25 r.p.s.
Number of armature lines	=	15,000
Number on each spool	=	3000 or 1500 on each half spool
Winding spaces, on each half spool	=	0.75" long 0.63 max + 0.38 min. height. 0.5 mean.
Gross section of spaces	=	0.375 sq in: Allow 30% 0.280 sq in.
Section allowed per lines	=	1.867×10^{-4} sq. in.
Diameter of wire	=	1.367×10^{-2} = 0.0137" silk covered
" " "	=	0.010" = # 31 B.W.G.
Length of mean turn	=	5.2" = 0.435'
Length of wire	=	652.5' per half spool 1255' per spool 6275' on armature
Weight " "	=	0.198 lbs 0.4 lbs 2 lbs.
Res: cold "	=	68w 136w 170w between brushes @ 20°C
" warm "	=	78w 156w 195w @ 60°C
Number of commutator bars	=	40.
Diameter of armature	=	6.2" = 15.75
Number of plates in do	=	5 × 20 = 100.
Gross section of wire	=	0.75" × 0.75" = 0.5625 sq in. = 3.628 sq cms.
Flux density in core	=	16,670 at load.
Gross section allowed for field cores	=	2.25 sq in: = 14.5 sq cms.
Diameter of field core	=	4.3 = 1.69".
Centre flux	=	0.08 = 0.022"
Angle subtended by pole	=	82° = arc of 11.44" = 11.2".
Polar area	=	1.405 × 11.2" = 2.1.5 sq cms.
Reluctance of gap	=	$\frac{0.08}{21.5}$ = 0.00372 × 2 = 0.0075
All estimated reluctance	=	0.01.
MMF estimated at load	=	1200
Amp. turns	=	960
Effective speed of arm	=	2435' per min. = 1237 lines.
Circ. mil per amp in armature at load	=	400.
Mean diam. of field winding	=	2.4" circ = 0.628'
Wiring) Diameter of field wire	=	0.013" #29 B.W.G. S.S.C. to 0.020".
Total number of turns	=	6000. (3000 on each spool 105 turns per layer 29 layers)
Depth of winding	=	0.58".
Amp. turns at full load	=	1500.
Res: of field	=	238w cold @ 20°C, 273w warm @ 60°C (allowing field weight)
Drop in field at load	=	60 volts 68 volts
Energy in field	=	15 watts 17 watts
Weight of winding	=	2 lbs (1 lb. on each spool)
Resistance of machine	=	408w cold 470w warm between terminals
Drop at load	=	102 volts 118 volts.
	m	= 0.235

Test of Copper Bell Motor Meter 23rd Nov. 91.

The torque possessed by the meter was measured again to observe whether the magnets retained their strength.

No. of Obs	Rad. of shaft	Weight of Gearing	Clamping Extra weight	Observed	Amps	Torque cm-gms	Torque cm-gms per Amp	Mean torque cm-gs per amp.	Total weight lifted
1	0·2625	1·17	10	0·431	2·224	2·9327	1·318		11·17
2			20	0·75	3·87	5·5870	1·436		21·17
3			30	1·16	5·985	8·181	1·367	1·395	31·17
4			40	1·48	7·635	10·81	1·416		41·17
5			50	1·81	9·338	13·43	1·438		51·17
6			3·7	0		1·279	Friction in axle and measuring belt		4·67

The mean torque of 1·395 cm-gms per amp:
13·95 " " " A.E.M.U. of current
13690 dyne cms " " "
86·000 useful C.G.S. units.

Test of Inductive Capacity of Saturating Compounds.

24th Nov 91.

Two plates of zinc about one foot square and 0·75" thick were planed true in the planes, and then used as the plates of a condenser. The dimensions of this were.

Lower plate 30·95 × 30·30 = 937·6
Upper " 30·65 × 30·3 = 928·8 Mean 933·2
Mean clearance (small slats of glass about 0·5 × 0·5) = 0·0967

Capacity per sq. cm. = 1/12·57 × 0·0967 = 1/1216 = 0·82244
" total area = 933·2 × 0·8224 = 767·6 approx.
= 85·3 × 10^{-5} microfarads = 0·853 × 10^{-3}

The first pair of cast iron face plates had an area of 30·48 × 31·4 = 957·1
With air separation 0·0967 Charge 64 divs: 295 volts
" 2 Thicknesses of dry manilla wrapping paper aggregate Thickness 0·0328 Throw 307 divs: 295 "
Dielectric constant of this paper 1·63

Grey pasteboard dried 139 divs: 295 volts Thickness 0·156.
Dielectric constant of this pasteboard 3·5

White Cardboard fairly dry 173 divs. 0·063 (2 Thicknesses together) 130 volts " "
Air condenser 27·9 " 0·096
Dielectric constant of this pasteboard 4·07.

Hard Rubber 28 divs: 0·248 130 volts
Dielectric constant of this hard rubber 2·59

Same two White cardboard sheets as above, but dried thoroughly in Steam chest 95 divs 0·063 130 volts
Air 28 divs: 0·097
Dielectric constant 2·2.

On the Cost of a Power Transmission Plant for Butte Montana.

The power required at Butte is not specified, but is at present supplied by wood burning engines consuming 200 cords of wood daily. A cord of the very best wood is equivalent to one ton of coal while with white pine it is only equivalent to 3/10th of one ton. It may be assumed at 100 tons of coal in this instance burned in 24 hrs = 9333 lbs. of coal per hr. = 1667 H.P. utilized at 5 lbs. of coal per H.P. per hr. = 12.45 days 1250 KWTs. delivered. With motors of 90% commercial efficiency this would be 1400 KWTs. At 5000 volts pressure at the receiving station this would mean 280 amp. The conductivity most economical for this would be 280 × 123 = 34,440 or 360,000 cir. mils.

One # 6 B&S. wire has 41,000 c. mils and 9 would have 369,000.
The weight of one such wire per mile = 660 lbs.
" " " new - - - - - = 6040 - per mile.
" cost " - - - - - - = $1510 per mile @ $0.25 per lb.

The distance of transmission will be either 45 or 65 miles to large sources of waterpower costing nothing more than the collectors.

Criteria of cost for 45 miles

	$
1400 KWTs. of motors @ $60	84,000
45 miles of wire @ $1510	68,000
res: of this length . 0.15 ohms	
Total res: 6.75 ω.	
" drop 1890 volts.	
" 2000 volts.	
Pressure at generator 7000 volts.	
Power of generator 1960 KWTs @ $125	245,000
	$ 397,000
Cost of removal	$ 138,000

Criteria of cost for 65 miles

	$
1400 KWTs. of motor @ $60 -	84,000
65 miles of wire @ $1510 -	98,200
res: of this length = 9.75 ω	
Drop 2800 volts say.	
Pressure at generator 8000 volts	
Power of generator 2240 KWTs @ $125	280,000
	$ 462,200
Cost of removal	$ 259,000

If it were permissable to run the motors at 10,000 instead of 5000 volts, the current would be 140 amp: and the conductivity required 17,220 = 190000 cir. mils. The cost of this per mile one way would be $780 and for 45 or 65 miles $35,100 and $50,700 respectively. The pressure at generator would be 12,000 volts and 13,000 volts respectively.

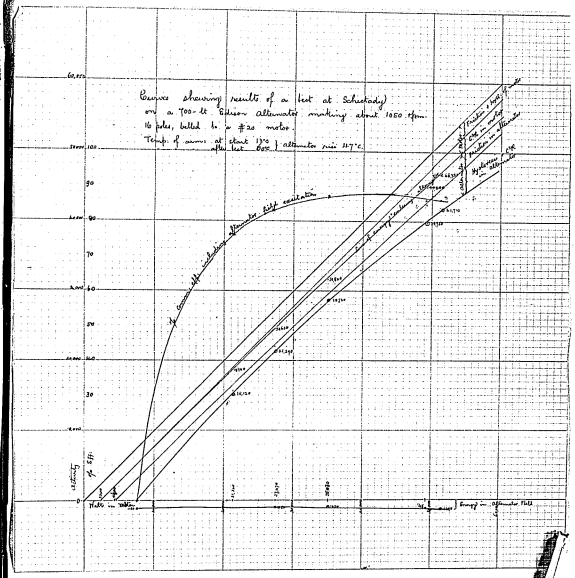
- waste in transmission - - 280 and 420 KWTs
- cost of this generator plant - $35,000 - $52,500 respectively.

	$	
1400 KWTs. of motors @ $60	84,000	84,000
45 miles of wire @ 780	35,100	
Power at generator 1400 KWTs	175,000	175,000
- - - 280 -	35,000	
	259,000	
Cost of removal	70,100	
	$. 329,100	

	$	
1400 KWTs. of motors @ $60.	84,000	84,000
65 miles of wire @ 780	50,700	
Power at generator 1400 KWTs.	175,000	175,000
- - - 420 -	52,500	
	259,000	
Cost of removal	103,200	
	$ 362,200	

$\frac{2335}{1035} \times \frac{720}{81} = 11.75$

Res. of alternator armature at start 1.31 Ω 13°C.
" shunt used to measure current 0.0003375 Ω.


Curves showing results of a test at Schenectady on a 700-kw Gibson alternator making about 1000 r.p.m. 16 poles, belted h.p. #20 motor.
Temp. of room at start 13°C after test 20°. Alternator rose 14.7°C.
Volts on 1000 cycles
Amps. in armature
Amps. in field
Kw. output
Efficiency
Kw. input
Volts on open circuit
Amps. in field
Amps. in armature
Kw. output

No. of Obs	P.D. at motor brushes	Current in motor	Energy in motor	c.p.	Mech. + friction	Energy left for alternator	P.D. at alternator terminals	Slip	Current		Amplified Current	Energy in alternator	Total energy in 20 ohm resistance wire
1	136	150	20,540	228	2300	18,240	768			18·2	18·2	13,970	13,920
2	132	190	25,080	361		22,340	845			21·9	21·9	18,510	18,570
3	128·5	240	30,120	576		27,244	942			24·3	24·3	22,870	22,970
4	122·	264	32,210	697		29,210	983			26·8	26·8	25,600	25,660
5	122	327	39,900	1089	3369	36,520	1080			30·46	30·46	32,890	32,970
6	94	570	53,600	3249	3549	48,050	915			42·2	42·2	38,800	38,870
7	109	450	49,050 / 49,750	2025	4325	44,725 / 45,425	1015			40·6	40·6	41,230	41,270
8	109	455	49,570 / 49,570	2070	4370	45,200 / 45,200	1020						
9	108	521	56,170 / 57,180	2701	4001	51,166 / 52,180	1027			42·3	42·3	43,440	43,520
10	114	504	57,240 / 58,680	2701	5001	51,286 / 53,686	1090			43·63	43·63	47,560	47,640
11	116	493	57,720 / 56,080	1764	4064	52,656 / 51,016	1015			40·	40	40,600	40,680
12	111	458	50,400 / 47,670	2061	4361	46,039 / 43,309	1035			40·6	40·6	42,030	42,110
13	113	470	53,180 / 50,260	2209	4509	48,671 / 45,751	1040	153	38·1	39·3	38·7	40,250	40,330
14	111	490	54,390 / 51,420	2401	4701	49,699 / 46,719	1020	178	40·74	40·09	40·82	41,630	41,710
15	105	470	49,350	2209	4509	44,840	998	160°	38·96	40·3	39·65	39,670	39,750
16	115	305	35,070	930	3230	31,840	980	90°	24·23	30·1	29·65	29,070 / 28,828	29,150 / 28,908
17	121	227	27,470	515	2815	24,655	1050	43°	20·20	20·2	20·2	21,210	21,290
18	123	173	21,340	301	2601	18,739	940	27°	16·03	16·0	16·0	15,040	15,120

Record of an Efficiency Test carried out at Schenectady Works on one of the Edison 700-light alternators 23rd Nov. 91.

The 700 light alternator was bolted to a #20 Edison standard machine operated as a motor. The fields of this motor were separately excited, and the energy so absorbed does not appear in the calculations. The current and pressure was measured at motor terminals by Weston instruments duly checked. The alternator pressure was measured by a 10-light transformer reducing in ratio 700:86 into a Weston Voltmeter. The current by Weston Ammeter. The energy in the field was also measured. From these data the efficiency is determined.

	P.D. at motor terminals	Current in motor armature	Energy in motor armature	Speed of motor	Speed of alternator	Current in alternator field	Volts at alternator terminals	Flux of alternator	Drop in alternator armature	Energy in alternator field	Hysteresis in latter.	Motor efficiency including losses
	volts	amps		r.p.m.		amps			volts			
	2294	180	4145	712	-							6.
		178	34	6052	706							11.5
	4721	175	38.5	6736	705							14.8
	46 7	132	35	4620	712	1057						12.3
	6243	130	49	6367		1057	9.4	804	6.3	59.2	556	1886	24.
	935	129	54	6964			11.4	930		71.8	819	2328	29.
	1879	128	59.5	7614		1032	13.5	1080		85.0	1147	2972	35.
	2982	130	69.	8970		1044	15.5	1260		97.6	1513	4315	48.
	3800	130	73.5	9554		1041	16.45	1330		103.6	1705	4893	54.

Load put on slowly applied.

P.D. on alternator terminals	Current in alternator field	Ks of alternator field	Energy in alternator field	Speed of alternator	Pressure on alternator with same current in load	Drop in armature	Difference between drop in armature and drop in coils	Drop due to coils	Energy lost in armature	Energy lost in coils	Energy lost in pole pieces and Foucault currents	Total energy lost in alternator	Commercial efficiency of alternator
59.	9.14	6.25	555	1070					4062			18,567	0.781
66	10.5	6.285	693	1070					3729			23,012	0.807
74	11.75	6.297	870	1073					4,274			28,114	0.817
79	12.4	6.37	980	1052					3,530			30,190	0.830
89	14.0	6.36	1246	1048					3,560			37,776	0.873
80	12.25	6.53	980	1050					170			49,030	0.793
87	13.5	6.45	1175	1070					2,085			44,950	0.928
87	13.25	6.57	1153	1070					4480			49,253	0.882
86	13.25	6.49	1140	1110					3416			52,196	0.913
88	13.25	6.64	1166	1053					1336			42,182	0.942
93	14.0	6.64	1302	1000					1200			44,611	0.904
93	13.8	6.74	1284	1063					8421			47,035	0.857
93.5	13.75	6.80	1286	1040					5039			48,035	0.868
92	13.5	6.89	1286	1030					5090	2830	2260	46,096	0.862
85	12.3	6.91	1046	18 58					4498 / 3148	1580	1110 1580	22,886	0.886 0.920
85	12.3	6.91	1046	1060					3365	.720	2.645	25,701	0.828
88	12.3	6.98	1046	1042					3.619	1461	3178	19,785	0.764

Ma

Connected w

No. of Obs.	Weight Grms.
	10
	20

DATA AND DIRECTIONS FOR USING THE EDISON A. C. VOLTMETER.

Unscrew front cover, and unwrap the scale beam and counter poise. Insert the aluminium pointer in its socket on the beam. Loose the screw that holds the clamp of the inner solenoid and detach the clamp, screwing it up out of range. Attach the inner solenoid carefully to the hook on the beam earring, so as to leave the connecting wires loose and free. Attach the brass counterpoise to the other earring and set the chain on the pan. Adjust the level of the instrument by use of the plumb bob, connect the two outer terminals to the alternator brushes and screw on the face plate. The instrument will then be ready for use.

Resistance of instrument at 26° C. 11,200 ohms.
Resistance hot - 72° C. - 11,385 ohms.
Resistance of # 36 B&S. guage - 0.005" - german silver bare wire wound on ten wooden grids, non inductively. Each grid holding about 115' of wire.
Resistance of inner solenoid 28 ohms warm.
Resistance of outer solenoid 190.5 ohms warm.
Inductance of both solenoids and of entire instrument 0.53 Henry at no load, 0.61 H at 1050 volts, and 0.67 H. at 1200 volts.
Angle of lag for instrument 8 degrees.
Factor of impedance 1.0028
Winding of solenoids
Inner solenoid 4 layers of # 33 PWG. silk covered.
Outer solenoid 14 layers of same # 33 PWG. silk covd. copper
Electromagnetic pull at 960 volts 6.5 grammes weight
at 1200 volts 7.09 grammes weight.
Weight of inner solenoid 27.5 grammes.
Weight of beam and counterpoise 67 grammes.
Ratio of beam lever 2 : 1
Length of pointer 12".
Full load rise of temperature 50° C.
Current in instrument at 1136 volts 0.1 ampere.
Energy expended in instrument 114 watts.
Weight of instrument complete 18 1/2 lbs.
Outside dimensions 10 1/2" x 10 1/2" x 9 7/8".
Fuse wire platinum 0.002" diam.
Carrying capacity, or fusing current 0.65 ampere.
Sheets of asbestos paper separate the wooden resistance grids
Copper wires making connection with the inner solenoid are very thin and flexible, hanging in long spirals to leave beam free.

Magnetic Test of Coppon Bells Meter 1st December 91.

Connected to scale pan by a cord over pulley to meter shaft.

Weight on Scale pan	Scale pan	Total Weight & Pan	Current of elevation	Current of descent	Mean current	Half 0·2625 Torque	Torque per amp.	Mean Torque per amp. of descent Torque
						cm-gram	cm-gram	
10	0.69	10.69	2.617	1.424	2.020	2.806	1.389	
20		20.69	4.951	3.680	4.265	5.431	1.267 ?	
30		30.69	6.373	5.366	5.87	8.056	1.372	1.376
40		40.69	8.262	7.223	7.752	10.681	1.378	Meiling #2
50		50.69	10.79	8.72	9.755	13.306	1.365	

Test of Alternating Current High Tension Voltmeter 3rd Dec. 91.

Resistance of the instrument is 11,200 ω @ 26 °C.
11,265 ω @ 72°C. temp. on bof gauge.

Resistance of the solenoids are = stationary 190·5 ω warm 185·5 ω cold
moving 28 ω " 27 ω
both 218·5 " 212·5

Inductance of the two solenoids in series, by accelerometer :—

At zero of scale 100~/sec 213·6 @ 26°C. 2·48 ᵐ = 530 ᵐ.
" 1050 " " 2·85 = 609 ᵐ.
" 1200 " " 3·13 = 669 ᵐ.

Inductance of entire instrument 11,200 ω 100~/sec 0·85 = 59 ᵐ. at 100~

Tan θ for full load = 0·0533 = 3° 3'.

Impedance = r (1 + 0·00282) = r (1·0028)

Fine wire 0·002" platinum, brass faces at Block 0·125 = 0·657

Distance between fulcrums and solenoid knife edge 3·775
" " " counterpoise " " 7·69

2" of Phosphor bronze double link chain, attached to counterpoise.

Electromagnetic pull at 960 volts, the starting point, = 6·5 gm. weight
" " 1200 " " = 7·09

Weight of moving solenoid 27·52 gm. Beam counterpoise, opposite 66·5 gm. wire.

Dimensions of finished instrument 19¾" high x 10½" broad x 9 ⅞" base depth.

Face plate 16" x 8 ⅞".

Outer solenoid 3·75" long, 3.35" interflange, 1·9 mm. int. diam. 2·8 mm. diam. over wire

Inner " 3·35" bf of hook to brass, 4·95" flange lengths, 4·7" interflange
0·3" diam. over wire.

114 layers of #33 B.W.G. copper wire silk covered on outer solenoid
10 " " " " " inner "

Length of pointer 12".

Phase between pointer extremities indicating 1000 volts + 1100 volts = 5·6 mm

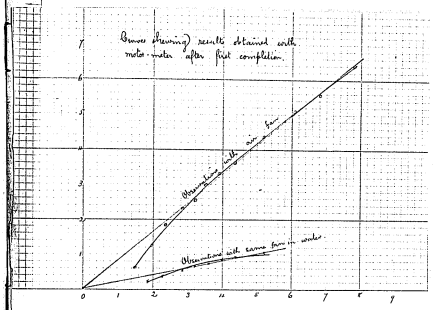
Full load rise of temperature in resistance box 50° C.

Weight of instrument complete 13¾ lbs.

Current in " at 1136 volts = 4·08 amp.

Energy " " " " = 112·6 watts.

Res. of instrument @ 75°C 11,350 ω, just removed from circuit.


Brown (flowing) results obtained with
water-meter after first completion.
Observations with new gas-meter
Observations with worn gas-meter
0
1
2
3
4
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8
9

Test of Edison-Patent Motor Meter on first completion. Dec 31st 91.

Resistance of armature between brushes 0·107Ω @ 23°C.
" " field. 0·09Ω.
The armature shaft is coupled to the fan shaft for liquids, but the fan was operated in air during the first series.

No of Obs.	Number of Lamps	Obsvd.	Amps.	Time.	Revs. p.m.	R.p.d.
1	3	0·285	1·471	1 min.	36·5	0·608
2	4	0·377	1·945	"	75	1·25
3	5	0·462	2·384		110	1·83
4	6	0·548	2·828		139	2·32
5	7	0·620	3·199		163	2·55
6	8	0·680	3·509		180	3·0
7	9	0·750	3·87		200	3·3̄
8	10	0·850	4·386		217	3·62
9	12	1·005	5·184		262	4·37
10	14	1·175	6·061		295	4·92
11	16	1·322	6·820		335	5·58
12	18	1·510	7·790		385	6·42
13	20	1·750	9·028		403	6·72
14						

Second series using water in the tub.

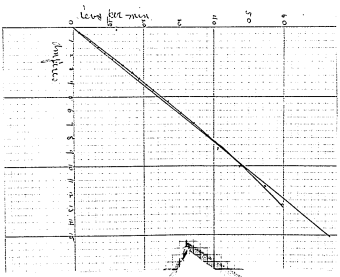
No of Obs.	Number of Lamps	Obsvd.	Amps.	Time.	Revs. p.m.	R. p. s.
1	4	0·356	1·837	1 min.	12·5	0·208
2	5	0·442	2·281		21	0·35
3	6	0·532	2·748		33	0·55
4	7	0·623	3·215		38	0·633
5	8	0·697	3·596		44	0·733
6	9	0·769	3·968		50	0·833
7	10	0·848	4·376		56	0·933
8	12	1·008	5·20		64	1·067

Analysis of Street Car Motors of the Edison General Co.

(100)

	# 14	# 16	Type A.
Cross section of field at neck	132.4 sq. cms 363 sq. cms	175 sq. cms. 377.5 . .	285.5 sq. cms values
Stated value of Leakage factor	1.16	1.16?	1.25?
Total field flux on this value	14,120,000	6,510,000	4 poles 5,950,000
Flux density in frame	18,570 C.G.S.	18,600 C.G.S.	14,250 20,850 C.G.S.
" " " neck	13,560	17,250 . .	
Length of Mag. ckt. in field	46.5	51	65 cms.
Total reluctance of Mag. ckt.	11.9 ×10⁻⁶ in Brass = 19.9 ×10⁻⁶	6.8 ×10⁻⁶ in Brass = 13.8 ×10⁻⁶	8.55 in air 16.9 in = 25.45 ×10⁻⁶
Turns on field coils each	4 pole wound 2 pole 192 outside	2 pole wound 1 pole 128 outside	14 pole turns on each spool
Mean amp. turns at full load	6240	7350	18kg (@ 85°)
M. M. F.	7800	9180	12,860
Calculated reluctance from MMF & flux.	18.4 ×10⁻⁶	14.1 ×10⁻⁶	25.72 ×10⁻⁶
Torque at full flux at arm shaft	14.4 in ×10⁶ × 2.54 cm/in ×10⁻⁵ = 6.32 kg-m	5.6 ×10⁶ × 2.54 ×10⁻⁵ = 4.50 kg-m	5.0 ×10⁶ × 2.54 ×10⁻⁵ = 4.45 kg-m
Torque at car wheel shafts	217 lbs. @ 1 foot	333 lbs. @ 1 ft.	341 lbs @ 1 foot
Pull at car wheel/wheels	911 . . .	1400 . . .	1432 . .
Weight of motor without gears	7288 lbs.	1120 lbs	1147
" " with	1610 lbs.		
	1800 .		
Full Speed of car at [illegible]	450 ×π×2 ÷ 11.2 = 252 mph	390 ×π×2 ÷ 11.2 = 218 mph	400 ×π×2 ÷ 11.2 = 224 mph
Weight of car allowed	loaded = 11 tons = 22,000 lbs	loaded 11 tons = 22,000 lbs.	loaded 11 tons = 22,000 lbs.
Head wgt @ 15 lbs/sq. in	165 lbs. on full.	165 lbs.	165 lbs.
Balance of pull left by 2 motors	1234 lbs @ full load	2075 lbs @ full load 100%	2130 lbs @ full load 103%
% grade attainable at [illegible]	5.6 %.	9.4 %	9.7 %
Work done in hauling car @ 9.5 mph up 5 % grade	27.8 HP.		
Observed power	18.5 B.H.P. Magneto 25% 4.6 HP 14.0 B.H.P. 2 arm Belt 56%		19.3 B.H.P. Magneto 25% 4.8 HP
Temperature obsd:	35° C. rise on armt 20° C. " field 30?	23° C. rise on armt 21° C. " field 40?	60° C. rise on armt 34° C. " field.

	Quadruplex # 14 S.R.	Duplex # 16. S.R.	Type A.
Length of magnet frame	25 7/8" 65.72	30 ¼" 76.84	35 ½" 90.5
Distance between support centers	29.1" 73.9	32.75" 83.18	33.5 83.76
Breadth of magnet frame	11 ⅜" 28.9	13 ⅜" 33.94	12." 30.48
Length of shaft between bearings	19 ⅞" 48.34	21.25" 53.97	24 ⅛" 57.19
Depth of magnet frame	25" rem bet flanges 23 ⅞"	23.5" rem bet flanges 23 ⅞"	20" rem each flange 21.5"
Diameter of armatures	15 ⅝" 40.25	18.25" 46.35	18.90" 48.37
Polar bore	16.125" 40.95	18.19" 46.91	18.25 47.02
Clearance or entrefer	9/16" 0.357	0.11" 0.279	0.125" 0.322
Breadth of armature	11 ⅜" 28.9	12." 30.48	12.0 30.48
Internal diam. of armature	9 ⅞" 24.45	11 ⅜" 28.41	13.75" 32.38
Bolt Holes	8 @ 0.55" 1.397	10 @ 0.55" 1.397	8" @ 0.55" 1.397
Bore diameter in armature	14 ¾" 37.23	16 ¾" 42.86	16 ¾" 42.547
Core depth	2 ⅜" 6.089	2 ⅜" 7.2214	1 ¾" 5.037
Gross section of core	25.9 ×2 ×2.54 ×4 = 152.5	30.7 ×2 ×2.54 ×2.52 = 204	28 ×2 ×2.54 ×5.037 = 130
Minimum allowing for bolts	116	160	92.8
Number of slots	60	70	72
Size of each slot	0.922 ⅞" × 1⅜" × 1.588	0.872 ⅞" × ⅝" 1.746	165 ⅛" × ½" 1.0247
Size of each bottle	⅜" × 1⅜" 1.588	1.746 ⅝" × 0.466 1.16	165 0.325" × ⅛" 0.825 0.175" 0.450
Brass section of each bottle	24.7	36.2	21.56 total 22.72 cm²
Number of teeth under pole	12	13	12
Polar area	23.8 ×16 = 600 sq. cms.	26.5 ×31 = 821 sq cms	30 × 25 = 750
Reluctance of each airgap	5.95 ×10⁻⁶	2.729 in² / 821 in² = 3.20 ×10⁻⁶	332 in² / 750 cm² = 4.43 ×10⁻⁶
Mean length of mag. ckt in arm	20	25	25
Number of turns in each slot	24	18	24
Total number of turns in arm	1440	1260	1728
Number of commutator bars	120	140	144
Size of conductor	# 16 B.&S. = 0.0508"	# 15 B.&S. = 0.0641"	# 17 B&S. 0.045" 0.0508" 38
C.mils per amp. at full load.	3444	4110	0.462
Space factor in each slot.	0.444	0.456	0.184 @ 20° C.
Resistance of each slot	0.250	0.128 @ 20°C.	0.828 = @ 20°C.; 0.947 @ 65°
Res. of arm. between brushes	0.00120 Ω, 0.937 @ 60°C	0.0520 @ 22°C. 0.692 @ 60°C	2g volts 33.3 volts
Drop in arms at full load	2.8.1 volts	28 volts	315 volts 165 volts
Energy " "	263 watts +20 for hyst = 1083 watts	1120 watts + 200 for hyst = 1320	+ for hyst. + for hyst.
" " " per sq cm.	14.29 sq cms. per watt.	4.72 sq cms per watt.	
	Two mains each brush.	Two mains each brush.	2 mains each brush.
Number of field spools.	24 Ω, 0.65 Ω in coil = 1.44 Ω in ckt	28 Ω, 0.8 Ω in coil = 1.96 Ω in ckt	15 Ω, 0.5 Ω per spool = 1.96 Ω in ckt
Winding on each spool	4.56 @ 20°C. 52.8 @ 60°C	2.76 Ω @ 20°C. 3.16 @ 60°C	2.84 @ 20°C. 3.32 @ 60°C.
Resistance in series	0.504 @ 20°C. 0.58 @ 60°C.	0.31 @ 20°C. 0.351 @ 60°C.	0.32 @ 20°C. 0.36 @ 60°C.
" multiple	15.12 volts 174 watts	12.4 volts 140 watts	11.2 volts 126 watts
Drop in field parallel at full load	4.55 volts 522 watts	4.96 volts 560 watts	3.92 volts 441 watts
Energy " "	0.83 watts per sq cm	0.636 watts per sq cm	0.197 watts per sq cm.
" " per sq cm. interruption	630 sq. cms.	880 sq. cms.	2224 sq. cms.
Surface of field coils	420 rpm / Volts 259	Magneto 420 rpm 303 ; 2 pole 420 ; 2 arm 420	Magneto 225 rpm 301 , Magneto arm 225, 303
Observed speed of motor	4.2 volts.	3.8 volts 4.2 volts 2 volts	3.9 volts 8.2 volts
Drop at this speed.	4.68	4.65 4.60 4.50	4.60.7 . 8.11.8 .
E.M.F. of armature	6405	6805 707 704?	6503 8213
E.M.F. of arm: for max power	4,240,000	5,619,000	3,763,000 4,742,000 ?
Calculated useful flux.	max. 18,230 at bolt holes {16,000 in frame}	11,050 at bolt holes 16,680 in frame.	{14,450 at bolt holes 16,250 in frame} 18,350 ?
" flux density in arm	20/120 ×0.005 = 0.0083	25/130 ×0.005 = 0.00961	20/150 ×0.005 = 0.0040 65/1.85 ×0.005 = 0.00176
" work. " field	46.8/460 × 0.005 = 0.00865	51/130 ×0.005 = 0.00971	
Reluctivity of armature			
" field cores.			
Polar angle	65° 30'	65°	
Volume of iron in armt	771.8 ×2.5 ×3.9 ×0.92 = 1873.0 cm³	933 ×30.5 ×8.9 ×0.92 = 2,160 cm³	
Mass of iron in armt	1123.8 kgm = 316 lbs.	2.04 kgm = 4.50 lbs.	
Cycles of magnetization per sec:	15	13	
Hysteresis at full load	250	300	
Surface of armature	4800 sq cms	6700 sq. cms.	


Longueur en mm
0
10
20
30
40
50
Graphique

Tests of copper bell meter 4th Dec. 21.

Torque measurements as follow:—

No. of Obs.	Weight Lbs.	Bearings	Total wt. Lbs.	Ascending current	Descending current	Mean Current	Mean = 0.2445 Torque	Torque per amp.	Mean
							oz-ft		
1	10	0.69	10.69	2.372	1.600	1.986	2.806	1.413	
2	20	"	20.69	4.592	3.643	4.118	5.431	1.319	
3	30	"	30.69	6.502	5.470	5.936	8.056	1.357	1.363 ± 0.017
4	40	"	40.69	8.549	7.224	8.037	10.681	1.329	
5	50	"	50.69	10.53	9.236	9.881	13.306	1.346	
6	1	"	1.69	"	"	"	0.444	0.262	

Speed measurements as follow:—

No. of Obs.	Lamps in ckt	Obsvd.	Amp.	Speed r.p.m.	
1	1	0.087	0.449	1.75	
2	2	0.198	1.022	4.9	
3	3	0.287	1.481	7.3	
4	4	0.359	1.852	9.3	
5	5	0.4414	2.291	11.3	
6	6	0.535	2.761	14.0	
7	7	0.636	3.282	16.4	
8	8	0.721	3.720	18.6	
9	9	0.808	4.169	20.9	
10	10	0.885	4.567	22.4	
12	12	1.045	5.392	27.1	
12	14	1.205	6.218	30.5	
13	16	1.350	6.966	34.3	
14	18	1.510	7.792	38.0	
15	20	1.690	8.720	41.2	
16	22	1.914	10.01	47.5	
18	26	2.23	11.51	54.5	
19	30	2.48	12.80	59.5	

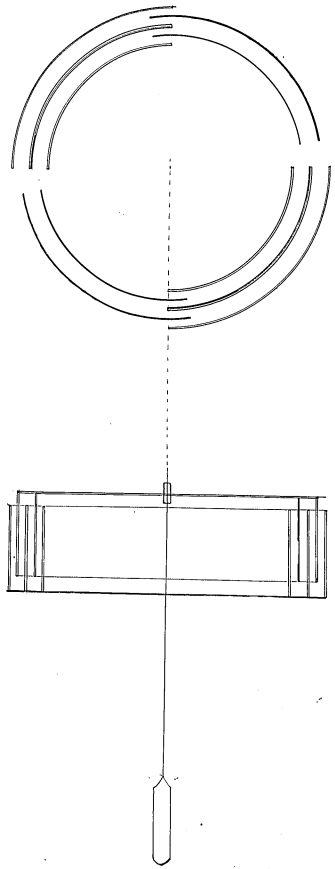
Magnetic Test of Copper Bell Motor 5th Dec. 91.

Torque measurements as follows:-

No. of Obn	Weight lifted	Including carriage	Ascending Current amp.	Descending Current amp.	Mean	Torque	Torque per Mean amp
1	0.2	0.99	0	0	0	0.26	
2	10.0	10.79	2.219	1.961	2.090	2.832	1.355
3	20.0	20.79	4.283	3.715	3.999	5.457	1.365 1.426 ±0.022
4	30.0	30.79	5.882	5.108	5.495	8.082	1.471
5	40.	40.79	7.740	7.018	7.379	10.707	1.451
6	50.	50.79	9.391	8.566	8.979	13.332	1.486

Tabulated results of Torque measurements.

No. of Obn	Date	Days from start	Mean torque per amp	% probable error	Hours per mean	Frictional Torque	
1	18. XI. 91	–			4.2		
2	19.	1	1.140 ± 0.025	1.8			
3	20th	2	Belt balanced + replaced				
4	21st	3	1.995 ±		4.4		
5	23rd	5	1.395 ± 0.018	1.3		1.279	
6	14th XII.	16	1.363 ± 0.017	1.2	4.8	0.4444	
7	5th	17	1.426 ± 0.022	1.6		0.26	
8	7th	19	1.378 ± 0.009	0.7		0.234	
9	8th	20	1.397 ± 0.006	0.4	4.8	0.1814	
10	9th	21	1.403 ± 0.016	1.2		0.837	
11	11th	23	1.383 ± 0.007	0.7		0.184	
12	14th	26	1.405 ± 0.0035	0.25		0.28	
13	17th	29	1.374 ± 0.017	1.2			
14	18th	30	1.391 ± 0.007	0.5			
15	19th	31	1.397 ± 0.005	0.35			
16	20th	34			4.72		
17	25th	40	1.399 ± 0.007				



(b) Dimensions for an electrostatic voltmeter of 1000 volts f.s.

Let r = the effective radius of the movable aluminium sheets. cms.
h = their height cms.
d = " distance from the fixed metal sectors.
α = the coefficient of induction of the movable sectors on themselves
β = " " " " " fixed " " "
γ = " " " " mutual " " 1 movable " the fixed
W = " energy of the system (electrostatic) A.S.U.
θ = " angle of displacement of the movable sectors from zero. (cm.)
m = " moment of electrostatic forces round the axis dyne-cms.
v_1 = " potential of the movable conductor system
v_2 = " " " fixed " "
n = " number of active surfaces

$$W = \tfrac{1}{2} v_1^2 \alpha + \tfrac{1}{2} v_2^2 \beta + v_1 v_2 \gamma$$

$$\alpha = v_0 + \frac{n\pi h\theta}{4\pi d}, \quad \beta = \beta_1 + \frac{n\pi h\theta}{4\pi d}, \quad -\gamma = -\left(\gamma_1 + \frac{n\pi h\theta}{4\pi d}\right)$$

$$m = \frac{dW}{d\theta} = \frac{v_1^2}{2}\frac{d\alpha}{d\theta} + \frac{v_2^2}{2}\frac{d\beta}{d\theta} + v_1 v_2 \frac{d\gamma}{d\theta}$$

$$= \frac{n\pi h}{8\pi d}\left(v_1^2 + v_2^2 - 2v_1 v_2\right)$$

$$= \frac{n\pi h}{8\pi d}\left(v_1 - v_2\right)^2$$

If now τ = the torsional modulus of the suspension wire
l = its length.
$m = \tau\theta/l$ and equating moments,

$$\tau\frac{\theta}{l} = \frac{n\pi h}{8\pi d}\left(v_1 - v_2\right)^2$$

In the instrument outlined on the opposite page
τ = 5 approx. $h = 2.5$ $d = 0.25$ $n = 4$ $l = 20$ $\theta = \frac{25}{360}\pi$
$\Delta v = 3.75$

$$\therefore \tau = \frac{20}{1\cdot3}\cdot\frac{4\cdot5\cdot2.5}{8\cdot3\pi4\cdot0.25}(3.75)^2 = 1720$$

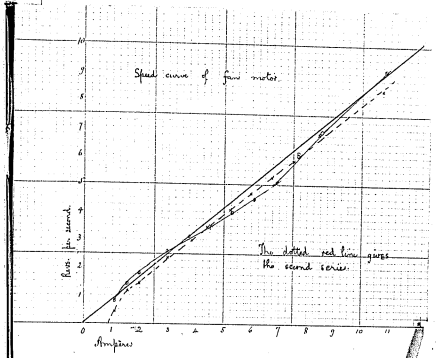
If n = rigidity of the metal (phosphor bronze $n = 4.5 \times 10^{11}$)
a = rad. of wire

$$\tau = \frac{\pi}{2}\cdot n a^4$$

$$\therefore a = \sqrt[4]{\frac{2\tau}{n\pi}} = \sqrt[4]{\frac{3440}{14\cdot14\times10^{11}}} = \sqrt[4]{\frac{243\cdot3}{10^{11}}} = \sqrt[4]{2433\times10^{-12}} = \sqrt[4]{243\cdot3\times10^{-10}}$$

$$= \sqrt{249\cdot3\times10^{-4}} = 7\cdot02\times10^{-3}$$

The diameter of the copper suspending wire should therefore be 0.014 cm
= 0.0055". Length 4" above and below.


Speed curve of fan motor.
Revs. per second.
Amperes
The dotted red line gives
the second series.

Test of Motor Meter in Patent Unit, with air fans 7th Dec. 1891

This meter is now provided with a pair of planes rectangular aluminium fan blades. The following speed observations were made.

No. of Obs	No. of Lamps	Ohms	Current	Revs.	Time	R.p.m.	R.p.s.
1	2	0.213	1.099	49	1'	49	0.813
2	3	0.295	1.523	83		83	1.363
3	4	0.381	1.966	107		107	1.783
4	6	0.570	2.942	154		154	2.566
5	8	0.728	3.757	188		188	3.133
6	10	0.877	4.525	209		209	3.483
7	12	1.020	5.263	238		238	3.966
8	14	1.175	6.062	267		267	4.45
9	16	1.335	6.888	303		303	5.05
10	18	1.485	7.661	366		366	6.1
11	20	1.66	8.564	415		415	6.915
12	18	1.485	7.661	360		360	6.0
13	25	2.11	10.89	547		547	9.12

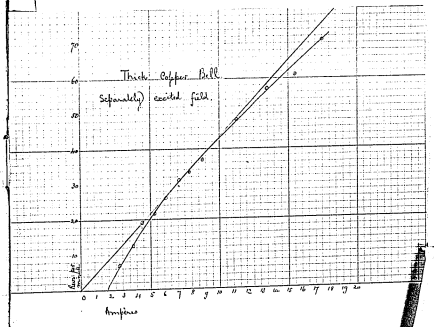
Second series as follows—

						R.p.s.	
1	2	0.211	1.089	25.5	1'	0.425	
2	3	0.295	1.523	70		1.167	
3	4	0.382	1.971	88		1.467	
4	6	0.574	2.962	139		2.317	
5	8	0.745	3.845	179		2.983	
6	10	0.861	4.444	208		3.467	
7	12	1.012	5.222	244		4.067	
8	14	1.160	5.985	280		4.67	
9	16	1.314	6.780	315		5.25	
10	18	1.460	7.532	347		5.783	
11	20	1.63	8.410	410		6.833	
12	25	2.08	10.73	503		8.383	

Test of experimental Municipal cut-out. 9th Dec. 91.

Forty lamps fitted with the newer cut out were tested twenty at one time $\frac{+200}{-200}$ Ohms, on about 1000 volts p.d. Fourteen of these cut into operation successfully, the remainder failed.

No. of Obs.
1.
2.
3.
4.
5.
6.
7.



Speed test of copper bell, meter 8th Dec. 31.

The reading of the instrument was measured as follows—

No. of Obs.	Lamps	Obsvd.	Amp.	Time	Revs.	Revs. p. min.	Revs. per amp. per min.	
1	1	0.092	0.475	1'	2	2	4.21	
2	5	0.429	2.213		11.4	11.4	5.149	
3	10	0.812	4.190		21.5	21.5	5.131	
4	15	1.214.0	6.398		31	31	4.845	
5	20	1.6145	8.486		40.5	40.5	4.773	
6	25	1.970	10.17		49	49	4.82	
7	30	2.41	12.44		57.25	57.25	4.603	

Capacity Test of Makerik :— 11th Dec. 31.

Oil (Burning) Kerosene oil.

Air condenser No. 1 Zinc plates 30.5 × 30.25 expansion 0.097 Mean Temp. 78 = 84.6
From " " 30.5 × 30.5 " 0.098 " " 86.5
Interpolated air condenser 73 div. = 74.6 div. equivalent
From condenser holding Kerosene oil 163.5
K. = 2.191
Third hearing oil for Lalmadee Batteries without success.

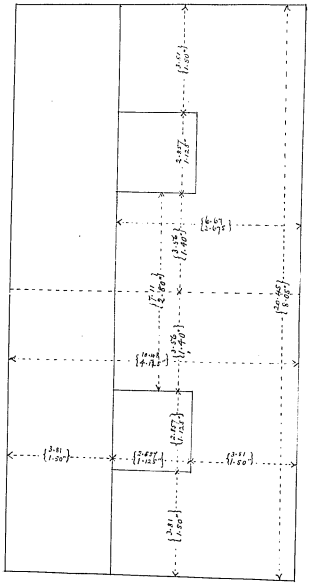
Test of a thicker copper bell in a series field meter 11th Dec.

The dimensions of this meter are shown on the opposite page. The strength of current in the fields was separately regulated (to about 1 amp.) until the same torque time obtained in this as in the original fullers was specified with permanent magnets. The speed was then observed as follows—

No. of Obs.	No. of Lamps	Obsvd.	Current	Speed. Revs. p. min.	Revs. per amp. per min.		
1	40	3.380	17.45	71	4.07		
2	35	3.0	15.48	61	3.941		
3	30	2.61	13.47	57	4.233		
4	25	2.18	11.25	48	4.267		
5	20	1.69	8.72	34.7	4.208		
6	18	1.52	7.843	33.4	4.258		
7	16	1.37	7.069	31	4.385		
8	14	1.19	6.140	26	4.235		
9	12	1.025	5.289	21.5	4.066		
10	10	0.861	4.443	17.6	3.962		
11	8	0.720	3.715	12.4	3.337		
12	6	0.553	2.853	6.8	2.383		

Full sized section of 100-Watt Transformer through plane of plates.

Finished core breadth 2.8" (7.12 cms).



Electromagnetic Design for a Transformer capable of being used for reducing pressure from 1000 to 120 volts on a voltmeter in a Central Station, in place of a high Resistance. (146)

Power	=	100 watts = 2 lamps.
Primary) effective voltage	=	1000.
Secondary) - -	=	120
Primary) current	=	0.257 at full load.
Secondary) -	=	1 amp. - -
Primary) winding	=	700 turns of # 27 S.W.G. : 0.016" d.c.c. & 0.028":
Secondary) -	=	84 - - # 20 - 0.035" - - - 0.048":
Length of mean turn	=	4 × 10 = 40 cms. 1.3'
- - primary winding	=	910 feet.
- - secondary) -	=	109 -
Weight of primary) coil	=	0.706 lbs. with collars say) 0.75
- secondary) -	=	0.405 - - - - 0.45
Total - - coils	=	1.111 - - - - 1.2.
Resistance of primary) coil	=	36.7 ω @ 20° C. 42.0 ω @ 60° C 47.3 ω @ 100° C.
- - secondary) -	=	0.918 ω - - - 1.05 ω - - - 1.18 ω - -
Drop in primary) at load	=	9.2 volts - - 10.5 volts - - 11.8 volts - -
- - secondary) -	=	0.92 ω - - 1.05 ω - - 1.18 ω - -
- - - due to pr. -	=	1.0 volt - - 1.26 volt - - 1.44 volt - -
Total drop in secondary) -	=	1.9 - - - 2.31 - - - 2.62 - -
Mean length of magnetic ckt.	=	25 cms.
Gross section of central core	=	7 × 6.4 × 0.93 = 41.7 sq. cms. effective.
- - - rest of -	=	7.6 × 6.40 × 0.93 = 45.2 - - -
Assumed value of Φ	=	160, 180
Maximum - - $\mathfrak{B}$	=	3840. Rest of ckt. 3540.
Area of air-gaps	=	44.8 sq. cms. in centre 42.6 on sides.
Winding space section	=	2.857 × 2.857 = 8.162 sq. cms. = 1.265 sq. ins.
L/A of magnetic ckt.	=	22/45.2 + 2/41.7 = 0.486 + 0.072 = 0.558.
Space occupied by) primary	=	700 × 0.026" × 0.028" = 0.509 sq. ins.
- - secondary	=	84 × 0.048" × 0.048" = 0.194 - -
Total - - winding	=	0.743 sq. ins.
Coefficient for insulation	=	1.7
Surfaces of iron on one side	=	10.5 × 20.45 − 16.3 = 214.7 − 16.3 = 198.4 sq. cms.
- - - other -	=	6.5 × 10.5 = 68.25 sq. cms.
- - - top	=	6.5 × 20.45 = 133.2 - -
Total surface of iron	=	400 × 2 = 800 sq. cms.
Volume of iron	=	198.4 × 6.5 = 1300 c.c. (cubic) =
Mass - - at 7.7.8	=	10140 gms = 22.35 lbs.

Weight of transformer Iron = 1.2 lbs. @ 0.20 = # 0.24
Sheet Iron = 22.35 - @ 0.05 = 1.12
Clamps = 1. - ? @ 0.05 = .05
Total 24.5 - $ 1.41 = # 0.70 per lb.

Primary) ckt waste	=	$0.25^2 \times 47.3 = 2.9$ Watts
Secondary) - -	=	$1^2 \times 1.2 = 1.2$ -
Total - -		4.1 -
Hysteresis - estimated		7.0 -
		11.1 -

Surface for watts = 11 sq. cms.

$\frac{(9996.7 + 163)\ 305.000}{996.7 \times 1.437}$

$\frac{10.169}{1452} \times 305.000 \times 42.5$

$9.24a \times 10^7$ per amp.

Air condenser area 922.6 sq: cms: separation 0.097 Mean throw 65.6 divs.
Iron " (air) 930.25 . - 0.098 - - 69.1 -
- - with perchlorinated napthalene 0.158 - - 161.7 -
Sp. Ind. Capy 3.773

This substance is a mixture of $C_{10}Cl_8$, ~~and~~ $C_{10}H_1Cl_7$ and homologous compounds. It formed an elastic plate, afterwards withdrawn from the condenser.
An alternating p.d. of about 1000 volt effective was brought to bear upon this condenser for about five mins: but without producing any appreciable change in its capacity.

Paraffine wax. while still molten :-
Air condenser 922.6 – 0.097 57 divs. reduced to iron air = 60.05
Iron - 930.25 – 0.098 (mean) 137 - Charge 146 – Disch. 128
Sp. I. capy 2.28

Same condenser cooled, 14th Dec: 91.
Air condenser 922.6 – 0.097 63.5 divs reduced to iron with air = 66.9 divs
Iron . paraffin wax mean = 166.5 175 divs charge, 158 divs, discharge
Sp. I. capy 2.49.

The leakage in both cases – hot and cold – was considerable, being some 20 divs: falling with the temperature while hot and 2 divs: cold. The difference between the charges and discharges renders the result doubtful.

Dec 14th Boiled heavy paraffin oil as used in Lalande batteries.
Leakage 30 divs Charge 178.5 Disch. 159 Mean 169.
Iron condenser 930.25 – 0.098 65.6 divs.
Air " " 922.6 – 0.097 63.2 - Sp. I. C. 2.576

Constant of Galv: as follows. 1 C. cell 300,000 + 5,000 = 42.5 divs.
From this the inferred deflection per ampere = 9.24×10^7 divs.
And the absolute resistance = $9.24 \times 10^7 \times e/d$
- - resistivity for the iron condenser $930.25 \times 0.098 = 8.77 \times 10^{11} \times \frac{e}{d}$
A p.d. of 288 volts at 12y gives on air condenser of zinc $\left\{\frac{922.6}{0.097}\right\} = 6403$ ...

Dec. 16th Tried a composition of less chlorinated napthalene in place of the perchlorinated napthalene of the 12th but the insulation was inferior.
Olive oil was also tried without success owing to inferior insulation
Creosote - - - - - - - . res. 600 ω
Phonograph cylinder wax was poured in hot. The resistance of the condenser so formed was very low. On cooling however the insulation improved.

Dec: 17th Same condenser of phonograph cylinder wax .
930.25 × 0.098 68.2 mean throw. with air
- 0.157 108.6 - . with cylinder wax.
K = 2.55
Lard oil was tried but with 10 cells the leakage was 25 divs:

Dec: 17th Condenser 930.25 × 0.098 68 mean throw
Same with stearic acid ~~49~~ 6.5 divs: Sp. I. K. 7.3
Zinc condr: equivalent 67 divs:
Leakage 5 divs. with 280 volts 2.5 divs with 104 volts.

Dec. 29th Zinc Condenser 922.6 – 0.097 112 divs
Iron - (air) 930.25 – 0.098 109.8 "
- . Stearic acid 930.25 – 0.114 133.3 × 3 = 400 divs
Zinc - (air) 922.6 – 0.097 66.5
65.2 reduction for thickness 56.0 divs
Iron condenser reduced value –

S. I. K. = 400/56 = 7.14

Fall of charge 133 – 107 in 60 secs: stearic acid = capy 0.00519

$R = \frac{.60\ \Omega}{0.0051 \log_e 1.2443} = \frac{60\Omega}{0.0051 \times 0.218} = \frac{60\Omega}{0.001112} = 54{,}000\ \Omega$

$\frac{54.000 \times 930}{0.114} = 4.406 \times 10^8\ \Omega = 4.406 \times 10^{23}$ sp. res @ 20°C

Collection of Results for Specific Inductive Capacities.

No.	Date & page	Substance	Formula	Testing voltage	Air condr. reduced theory	Observed mean theory	Sp. S. K.	Insulation Resistivity
1	24.XII.01 135	Paper	$(C_6H_{10}O_5)_n$	300			1·63	
2	" "	Grey pasteboard	"	"			3·5	
3	" "	Cardboard	"	130			4·07	
3bis	" "	" heated		"			2·20	
4	" "	Hard rubber		"			2·57	
5	11 XII.01 105	Commercial bayonet		220			2·19	
6	12. XII. 01 107	Paraffined Pasteboard	$C_{20}O_9$ + etc	"			3·77	
7	" " "	Paraffin wax	$C_{31}H_{64}$	"			2·5	$1·1 \times 10^{30}$
8	16th " "	Heavy Paraffin oil "Saturn" oil	"	"			2·58	$8·0 \times 10^{31}$
9	16th " "	Olive oil		280			—	10^{31}
10	17th "	Sand oil		20			—	$3·5 \times 10^{30}$
11	17 " "	Creosote		280			—	$5·4 \times 10^{25}$
12	" " "	Plaue sylvic wax		280			2·35	
13	"	Castor oil		1			—	bad
14	"	Stearic acid		108			7·3	$3·5 \times 10^{29}$
15	18th "	Plaue comp. #23						
16	29th "	Stearic acid		250			7·14	$4·14 \times 10^{33}$
17	30th "	Sperm oil		"			—	$7 \frac{1}{2} \times 10^{9}$
18	31st " 158	Bauf wax		312			40·0	high
19	31st " "	Crude ozokerite		"			very 2·75 (2·24)	high

Fig. 1.

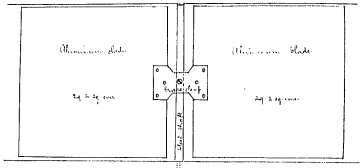
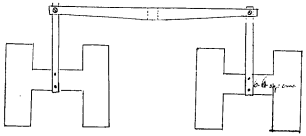
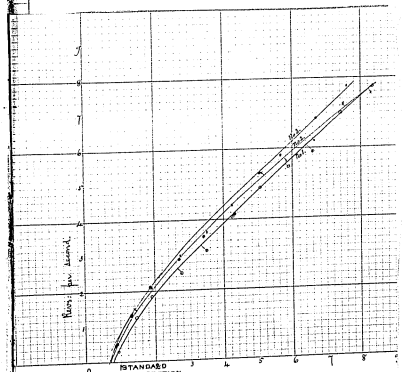

Aluminium plate
sq. ½ sq. cm.
Aluminium plate
sq. 2 sq. cm.
Steel shaft

Fig. 2.


sq. 2 sq. cm

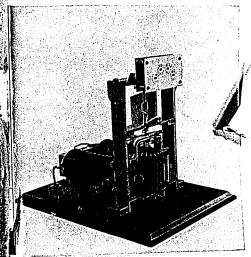

Meters per second.
0
1
2
3
4
5
6
7
8
STANDARD
CROSS SECTION.
10m² N°30.
Amperes through meter

Observations on the Patent Motor Meter. 11th Dec. 91

(114)

Three series of speed readings were taken as follows—
No 1. with a pair of fan blades represented in fig: 1 on the opposite page
" 2 " " " " " " 2 " "
" 3 " the fan shaft but with no fans attached to it.

No. of Obs.	Lamps	Ohms	Amps.	Revs p min	Revs per sec.
1	2	0·182	0·939	19·3	0·32
2	3	0·280	1·1118	75	1·25
3	4	0·265	1·8814	111	1·85
4	6	0·538	2·751	162	2·53
5	8	0·675	3·4814	187	3·12
6	10	0·836	4·263	244	4·07
7	12	0·983	5·073	293	4·88
8	14	1·140	5·882	328	5·47
9	16	1·280	6·606	352	5·87
10	18	1·435	7·4014	420	7·0
11	20	1·62	8·358	464	7·73
12	Fan #1 now replaced by #2, no other change				
13	2	0·169	0·872	31·5	0·53
14	3	0·274	1·1414	91	1·51
15	4	0·363	1·873	126	2·1
16	6	0·530	2·735	180	3·0
17	8	0·675	3·499	218	3·63
18	10	0·823	4·248	264	4·4
19	12	0·980	5·058	318	5·3
20	14	1·133	5·845	336	5·6
21	16	1·290	6·656	376	6·27
22	18	1·445	7·4614	436	7·27
23	20	1·605	8·282	452	7·53
24					
25	2	0·169	0·872	28·5	0·475
26	3	0·265	1·367	82	1·37
27	4	0·359	1·853	124	2·07
28	6	0·529	2·73	172	2·87
29	8	0·662	3·42	212	3·53
30	10	0·836	4·31	248	4·13
31	12	0·978	5·05	318	5·3
32	14	1·110	5·678	348	5·8
33	16	1·300	6·708	410	6·83
34	18	1·470	7·584	467	7·78
35					



Calibration of 7 am Motor - Meter for Edison Patent.

After the instrument had been prepared for delivery, the calibrations were made as follows:-

No. of Obs.	Amps.	Time	Revs.	Revs. p. min.	Revs per min per amp	Mean Rpm per amp
1	4	1'	172	172	43	
2	2		89	89	44.5	
3	3		133	133	44.3	
4	4		176	176	44.0	
5	5		220	220	44.0	
6	6		276	276	46.0	44.5
7	7		324	324	46.3	
8	8		360	360	45	
9	9		426	426	47.3	
10	10		420	420	42	
11	9		376	376	42	
12	2		80	80	40	

The primary coil was rewound having layer of 13 wires instead of 14. This makes it flatter and longer.

The gearing was suitably adjusted, and the resistance of the armature finally compensated to suit the gear dials. The final observations before delivering the motor were as follows:-

18th Dec. 91.

No. of Obs.	Amperes	Time	Revs.	R.p.m	R. p.s.	R. p. min per amp
1	10	1'	450	450	7.5	45
2	9		410	410	6.83	45.5
3	8		360	360	6.0	45.
4	7		318	318	5.3	45.4
5	6		274	274	4.57	45.6
6	5		223	223	3.72	44.6
7	4		176	176	2.93	44.
8	3		128	128	2.13	42.6
9	2		76.5	76.5	1.275	38.3

Motor delivered 18th Oct. 91.

Westinghouse 100 lt transformer

1000 volts at primary terminals

EMF at secondary terminals 48·5 volts no load

" " " 45·5 " full load 99 amp. 4·9 pm per.

Drop 3·0 " or 6.2 %.

Test of 5 KWT. 100 lt transformer on first completion Dec. 15th 91. (151)

The design of this instrument is given on page 130.

The weight of machine is 196 lbs.

" resistance of the primary = 0·78 ω @ 20°C

" " " secondary = 0·05 2ω " Ω any 40° C. (both in series)

Transformer connected up in usual manner, and the drop observed as follows:- 50 lamps of 16 cp 120 volts in each secondary 3 — mmo.

0 lamps. p.d. 117 100 Lamps 111·5, drop 5·5 volts at full load.

Observed following series for efficiency drop.

No. of Cks	Lamps.	Current	Pressure at S. terminals no load	P.D. at S. terminals loaded	Efficiency Drop
- 1	99	36·5 γ	116·5	113·0	3.5
- 2	90	34·4	117	114	3.
- 3	80	30·5	116·3	113·5	2.8
- 4	70	27·1	116.	113·5	2.5
- 5	60	23·35	116	114	2.
- 6	50	20·2	116·2	114·5	1.7
- 7	40	15·85	116·0	114·8	1.2
- 8	30	12.	116·6	115·5	1.1
- 9	20	9.	116·4	115·5	0.9
- 10	10	5.	115·9	115·5	0.4
- 11	99	37	119·0	115·3	3.7

Elevation of temperature $\frac{\text{surface of}}{\text{core}}$ of iron after 5 hours full load = 52°C.

The primary coil was most unwound to have layers of 13 wire instead of 14. thus making it flatter but longer. The full load drop is still 5·5 volts drop at terminals of secondary.

Res. of primary @ 20°C. 0·792 ω Weight 33 lbs.

" " secondaries 0·032 ω each. " 29 " together.

Inductance of primary in air 1000/n 9·766 ω 3.04 γ = 29.7 h.

" " secondary " 1000/n 2·187 ω 0·21 γ = 0·459 h.

Mutual " " primary to secondary 1000/n 9·765 ω $\begin{cases} 3.11\ \gamma \\ 2.775\ \phi \end{cases}$ = 0.6 m h.

" " both in 1000/n 9·760 ω $\begin{cases} 3.190\ \gamma \\ 2.915\ \phi \end{cases}$ = 1.35 h.

16th Dec. Elevation of temperature on surface of iron after 5 hours full load = 50°C.

Particulars relating to the Cost of Transmitting Power. 16th Dec. 01

5000 H.P. to be delivered over a distance of 35 miles from water power.

5000 H.P. = 3750 KWTS. Motor power for this @ $60 per KWT = $ 225,000

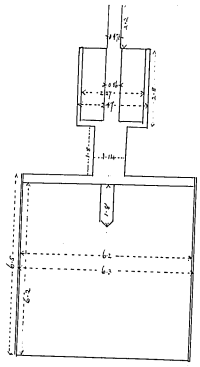
The terminal motor pressure being 5000 volts, and the commercial efficiency 0.9, the power at motor terminal = 4170 KWTS. and the current 834 amperes.

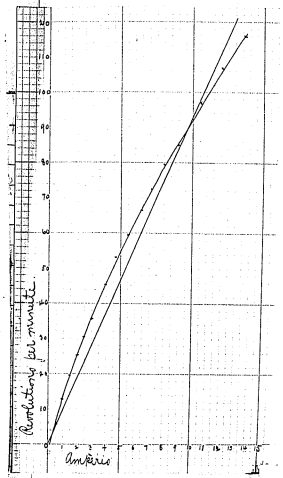
The most economical conductor would be 123 X 834 see p. 113 or 102600 ℔ = 1,100,000 c. mils.

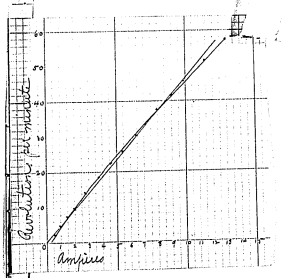
The cost of copper in this per mile is $ 4,400 and 35 mile =	$ 154,000
Erection of overhead wire @ $600 per mile	21,000
The resistance of this per mile = 0.0525 ω @ 35 mile = 1.834 ω	
allow 10% for grounds = 2ω	
Drop in conducting circuit = 1668 volts. Generator pressure 6668 volts, and generator activity at terminals 5560 KWTS @ 125	695,000
Total at the rate of $21 g per HP or $293.5 per KWT =	$ 1,095,000
Cost of plant if no intervening distance 3750 KWTS @ 60 = 225,000; 3750 KWTS @ 125 = 468,750; 693,750	693,750
	$ 401,250

2nd Case 5000 HP. delivered over a distance of 11 miles of open field

As before 5000 HP. = 3750 KWTS. Motor Power @ $60 per KWT. =	$ 225,000
Cost of conductor @ $4,400 per mile	48,400
Erection of overhead wire @ $600 per mile	6600
Resistance of this per mile = 0.0525 ω @ 11 mile = 0.5775 ω	
Allowing for grounds say 0.7 ω	
Drop in circuit 583.8 say 600 volts. Generator pressure 6600. generator activity at terminals = 4670 KWTS @ $125	583,750
	$ 863,750
Cost of plant if no intervening distance	693,750
	$170,000


62
63
198.5 gms.


Revolutions per minute
Ampères


Ampères

Test of #3 or Thin copper belt meter - 22nd Dec. 21.

The same series field coating was employed as for #2 vide p. 145
The torque was made equal to that in the E.M. meter by adjusting the strength of current in the separately excited field.
The following speed readings were then obtained:-

No. of Obs.	Meter	Revs.	Time	Revs. per min	Revs. per min per amp.	Amperes
1	#3 or Thin belt	6	1'	6	11.6	0.516
2		13.1		13.1	13.2	0.991
3		19.4		19.4	13.3	1.445
4		25.7		25.7	13.2	1.94
5		30.5		30.5	12.9	2.374
6		35.9		35.9	12.4	2.890
7		45.8		45.8	11.9	3.870
8		53.2		53.2	11.3	4.696
9		59.5		59.5	10.9	5.470
10		66.3		66.3	10.3	6.425
11		72.5		72.5	10.1	7.198
12		79.5		79.5	9.9	8.024
13		85		85.0	9.5	8.901
14		97		97.0	9.2	10.23
15		107		107	8.7	12.28
16		116		116.	8.5	13.67
1						0.516
1	#1 or Permanent Magnet machine belt.	2.21		2.28	4.28	0.516
2		4.76		4.76	4.78	0.996
3		7.06		7.86	4.85	1.445
4		9.60		9.60	4.94	1.905
5		14.1		14.1	5.12	2.753
6		18.4		18.4	4.88	3.767
7		22.3		22.3	4.86	4.592
8		25.8		25.8	4.81	5.366
9		30.1		30.1	4.72	6.373
10		33.7		33.7	4.70	7.172
11		37.5		37.5	4.72	7.946
12		41.5		41.5	4.65	8.927
13		45.5		45.5	4.65	9.804
14		51.5		51.5	4.54	11.35
15		57.6		57.6	4.45	12.95

Calibration of unifilar Dynamometer 28th Dec. 01.

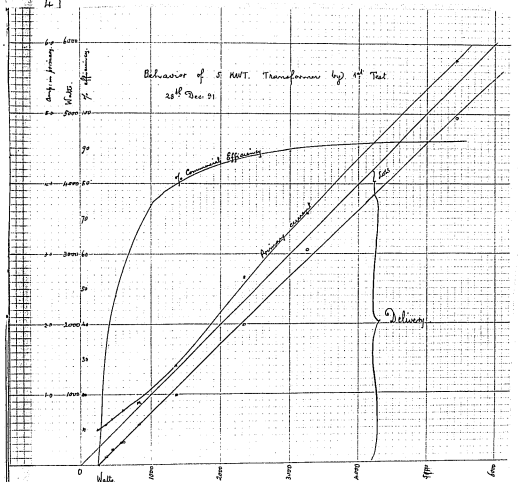
Coffin suspension wire 0·003".

No. of Obs.	Resistance out.	t.	Current in suspension	R.	Pd.	Calculation coil	Cc	τ	$\frac{C_c}{\tau}$
Coil #1	1	7580	12.5	0.016611	0·1Ω	0·488	4·88	0·48121	63°	1·177×10⁻³
	2	6010	12.3	0.02135	"	0·586	5·86	0·1251	10½°	1·197 "
	3	4·010	12.6	0.03142	"	0·582	5·82	0·1829	153°	1·189 "
	4	4·010	12.5	0.03179	"	0·624	6·24	0·2143	174°	1·232 "
									Mean 1·197×10⁻³	
Coil #2	5	7010	12.4	0·01817	1Ω	0·307	0·307	0·005379	4·5°	1·24×10⁻⁴
	6	7010	12.8	0·01826	2·08	0·633	0·3037	0·005568	4·3·5°	1·275 "
	7	7010	12.6·1	0·01799	0·1Ω	0·120	1·20	0·021519	17·2°	1·256 "
	8	7010	12.6·5	0·01805	0·1Ω	0·170	1·70	0·030649	24½·5°	1·257 "
	9	7510	12.6·8	0·01688	0·1Ω	0·198	1·98	0·033442	24·7°	1·252 "
									Mean 1·258×10⁻⁴	
Coil #3	10	7010	12.9	0·01755	1Ω	0·292	0·292	0·005125	2·6°	1·971×10⁻⁵
	11	7010	12.7·5	0·01818	"	0·307	0·307	0·005582	2·7·1	2·060 "
	12	7010	12.7·8	0·01823	10Ω	1·56Ω	0·156	0·0028446	1·4·1°	2·018 "
	13	7010	12.7·7	0·01821	1Ω	0·306	0·306	0·005571	2·7·5°	2·022 "
									Mean 2·018×10⁻⁵	
Coil #4	14	7510	12.7·4	0·016965	10Ω	0·770	0·077	0·0013306	1·6·6°	7·97×10⁻⁶
	15	7510	12.7.3	0·01695	"	0·578	0·0578	0·0010135	12·8·5°	7·886 "
	16	7010	12.6.0	0·01797	"	0·590	0·0590	0·0010680	13·3·5°	7·944 "
	17								Mean 7·809×10⁻⁶	

Suspension wire carried away by an accidental short circuit.

Name

No. of Obs.
1
2
3
4



Recalibration of Kohlrausch Dynamometer Dec. 28th 91.

For Suspensions were inverted, and following observations made:—

Coil No.	Res.	Emf	Current in Suspension	τ	p.d.	Current in coil	C_c	τ	$C_{\frac{c}{s}}$
1	1.0038	122	3.021×10^{-2}	0.1	0.186	1.86	5.619×10^{-3}	119.5°	1.135×10^{-1}
2	"	123.2	3.051 "	"	0.476	4.76	1.4525×10^{-2}	110°	1.320 "
3	"	124.3	3.127 "	"	0.670	6.70	2.095 "	150°	1.397 "
4	3113	126.2	4.054 "	"	0.674	6.74	2.733 "	206°	1.326 "
5	2.038	126.3	6.196 "	"	0.674	6.74	4.177 "	323°	1.293 "
								Mean	1.334×10^{-1}
6	5.043	124	2.159 "	0.1	0.205	2.05	5.041×10^{-2}	345°	1.461×10^{-1}
7	10,020	127	1.268 "	"	0.195	1.95	2.473 "	170°	1.455 "
8	17520	125.5	0.7162 "	"	0.195	1.95	1.397 "	102°	1.370 "
9	16,525	12.6	0.7624 "	"	0.194	1.94	1.479 "	105.5°	1.402 "
10	16,525	126	0.7624 "	2ω	0.936	0.478	3.645×10^{-3}	25.5°	1.430 "
								Mean	1.4236×10^{-1}
11	16,525	124.5	0.7534 "	2ω	0.920	0.460	3.466×10^{-3}	147°	2.358×10^{-1}
12	16,530	126	0.9314 "	2ω	0.940	0.470	4.379 "	175°	2.502 "
13	16,530	125	0.9238 "	2ω	0.370	0.185	1.709 "	72.5°	2.357 "
14	9,540	127	1.331 "	2ω	0.367	0.1835	2.443×10^{-3}	107°	2.283 "
								Mean	2.375×10^{-1}
15	9540	127	1.331 "	10ω	0.770	0.077	1.025×10^{-3}	120°	8.54×10^{-1}
16	7510	128	1.704 "	10ω	0.782	0.0782	1.333 "	133°	1.002×10^{0}
17	4.010	127	3.167 "	10ω	0.772	0.0772	2.445 "	219°	$1.116 \times$ "

The results for coil #14 are doubtful. But the constants for coils nos. 1, 2, 3 have with the new suspending wire increased beyond those on the preceding page by the respective ratios of 1.115, 1.133, & 1.171.

Efficiency test of 5 KWT Transformer 28th Dec. 91.

Set No.	Res. in sup. ckt.	α	τ	Energy in for ckt	Amp. in %	Load Lamps	Lamps	Amps.	Volts	Energy in Secondary
1	17,920	1.423×10^{-3}	107.5°	274	0.5	0	0	-	119	0
2	16,220	"	140°	363	0.57	1	1	0.45	-	107
3	18,170	"	175.5°	454	0.65	2	2	0.9 ?	117.5	212
4	18,400	"	228°	568	0.78	3	3	1.3 ?	119	309
5	18,100	1.334×10^{-3}	255	616	0.73	3	3	1.3 ?	120	310
6	18,520	"	335°	827	0.87	5	5	2.4	120	576
7	18,000	"	565	1357	1.40 + 1.46	10	10	4.114	120	994
8	17,580	"	99°	2314	2.66	20	20	8.50	117	1998
9	19,020	"	135°	3245	3.57	30	30	13.26	115	3058
10	17,520	"	159°	3716	4.76	40	40	16.86	119.5	4006
11	18,380	"	222°	5143	5.76	50	49	20.77	119.	4944
12										

Elementary conditions of operation in an alternating transformer.

Let e = the instantaneous simple harmonic emf. at pr. terminals
p = . pulsation or angular velocity $2\pi n$
r = . resistance of the primary circuit.
ρ = ... secondary . .
l = . inductance . . primary . (Constant)
λ = ... secondary (.)
μ = . mutual . . . pr. & sec. assumed constant.
c = . current in the primary ckt.
γ = ... secondary .
e = E.M.F. all in absolute measure.

Then
$$E\,\text{sin}pt - cr - l\dot{c} - \mu\dot{\gamma} = 0 \qquad (1)$$
$$\mu\dot{c} + \lambda\dot{\gamma} + \gamma\rho = 0 \qquad (2)$$

From (1) $\quad pE\,\text{cos}pt - \dot{c}r - l\ddot{c} - \mu\ddot{\gamma} = 0 \qquad (3)$

whence $\quad pE\,\text{cos}pt - \dot{c}r + p^2lc + p^2\mu\gamma = 0 \qquad (4)$

and from (1), (2)
$$\dot{c} = \frac{pE\,(pl\,\text{sin}pt + r\,\text{cos}pt)}{p^2l^2 + r^2} + \frac{\mu p^2(r\gamma - l\dot{\gamma})}{p^2l^2 + r^2} \qquad (5)$$

Substituting in (2)
$$\frac{\mu pE\,(pl\,\text{sin}pt + r\,\text{cos}pt)}{p^2l^2 + r^2} + \frac{\mu^2p^2(r\dot{\gamma} - l\ddot{\gamma})}{p^2l^2 + r^2} + \rho\gamma + \lambda\dot{\gamma} = 0 \qquad (6)$$

and hence
$$\dot{\gamma}\left\{\lambda(l^2p^2 + r^2) - \mu^2lp^2\right\} + \gamma\left\{\rho(l^2p^2 + r^2) + \mu^2p^3r\right\} = -\mu pE\sqrt{l^2p^2 + r^2}\,\text{sin}(pt + \tan^{-1}\tfrac{pl}{r}) \qquad (7)$$

or
$$\dot{\gamma}\left\{\lambda - \frac{\mu^2p^2l}{p^2l^2 + r^2}\right\} + \gamma\left\{\rho + \frac{\mu^2p^2r}{p^2l^2 + r^2}\right\} = -\frac{\mu pE}{\sqrt{p^2l^2 + r^2}}\,\text{sin}(pt + \tan^{-1}\tfrac{pl}{r}). \qquad (8)$$

Again differentiating (2)
$$\mu\ddot{c} + \lambda\ddot{\gamma} + \dot{\gamma}\rho = 0 \qquad (9)$$
$$\text{or} \quad -p^2\mu c - p^2\lambda\gamma + \dot{\gamma}\rho = 0 \qquad (10)$$

From (10) and (1)
$$p^2\gamma(\lambda l - \rho c) + \dot{\gamma}(p^2\lambda^2 + \rho^2) = 0 \qquad (11)$$
$$\text{or} \quad \dot{\gamma} = \frac{p^2\gamma(\rho c - \lambda\dot{c})}{p^2\lambda^2 + \rho^2} \qquad (12)$$

Substituting in (1) $\quad E\,\text{sin}pt - cr - l\dot{c} - \frac{\mu^2p^2(\rho c - \lambda\dot{c})}{p^2\lambda^2 + \rho^2} = 0 \qquad (13)$

or
$$\dot{c}\left(l - \frac{\lambda\mu^2p^2}{p^2\lambda^2 + \rho^2}\right) + c\left(r + \frac{\rho\mu^2p^2}{p^2\lambda^2 + \rho^2}\right) = E\,\text{sin}pt. \qquad (14)$$

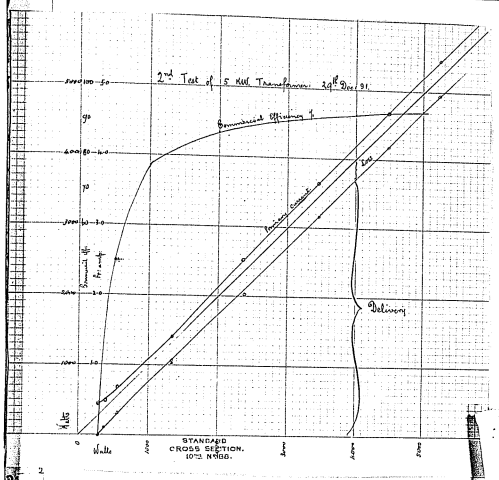
Since in a properly constructed coil $\frac{l}{\lambda} = \frac{N^2}{n^2} = \nu^2$ and $\mu^2 = l\lambda$ we can simplify expressions (8) and (14) which contain the values of the current (8) becomes when pl is large compared with r

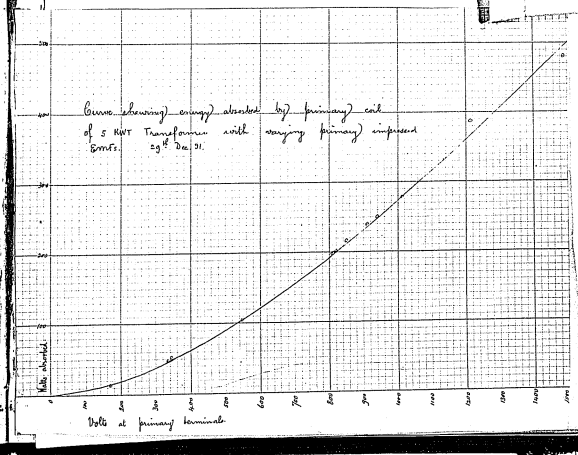
$$\gamma\left(\rho + \frac{r}{\mu^2p}\right) = -\frac{E}{\nu}(\text{sin}pt + \tan^{-1}r/pl) = -\frac{E}{\nu}\,\text{sin}pt \qquad (15)$$

and
$$c\left(r + \nu^2\rho\right) = E\,\text{sin}pt \qquad (16)$$

The current in the primary has the same strength as it would have in a non-inductive circuit of res. $r + \nu^2\rho$, and the current in the secondary that which would flow in a non inductive circuit of resistance $\rho + \frac{r}{\nu^2\rho}$ under an emf $-\frac{E}{\nu}$.

c and γ are in opposition or angularly distant by π
The ampère-turns of the two coils are thus in opposition.




Curve showing energy absorbed by primary coil of 5 KWT Transformer with varying primary impressed forces. 29th Dec. 91.
Watts absorbed
Volts at primary terminals

The peculiarity of this curve quantitatively lies in the apparent relation that doubling the abscissæ leads to a tripled ordinate.

That is if $x = 2^m$

$\frac{y}{a} = 3^m$

whence $y = ax\left(\frac{3}{2}\right)^m$ where $m = \frac{\log c}{\log 2} = \frac{\log c}{0.30103}$

$y = ax\,(1.5)^{\frac{\log c}{0.30103}}$

$= ax\,(3.8115)^{\log c}$

or $y = a\,3^{\frac{\log c}{0.3010}} = a\,3^{\frac{\log c}{0.30103}} = a\,b^{\log c}$

$\frac{dy}{dx} = p\frac{y}{x}$

Efficiency Test of Transformers 5 KW Ts. reperated 29th Dec. 91.

... connections as in test recorded p. 155.

Rev. in cct.	a	T	Energy in Pri. cct.	Amp. in Pri. cct.	Load Lamps	Lamps	Amps	Volts	Energy in Sec. Cct.	Efficiency
17620	1.1236×10^{-4}	112"	2.81	0.145	0	0	–	120	0	
17.920		1142	365	0.149	1	1	–	119	104	2.61
17.820		2.15.5	549	0.69	3	3	–	118	311	238
17.960		4.47" 15.57	1.06.57 13.57	1.141 1.140 : Dyn	10	10	4.888	120	1077 ℔ 220	
17.770	1.331×10^{-3}	61.5"	1458	1.140 1.126 Dyn	10	10	4.180	119.5	999	4.59 68.3
18.020		101' 97	2373 2312	2.525	20	20	8.540	119	2033	2.40 88.7
18.060		1.43.5 1.39.5	3.26.5 3.20.5	3.650	30	30	13.240	119.4	3161	2.96 1.99 91.5
17.920		1.9.1' 1.8.8	4.47.9 4.37.2	4.671	40	40	17.59	119.	4186	2.84 1.87 93.7
18.070		2.16.6" 2.12.5	5.34.9 5.27.21	5.450	48	50	20.88	118.5	4949	2.70 1.72 94.8
17.920		56.5"	1343	1.40	10	10	4.28	119.3	1021	322 76.0

Measurement of Exciting energy taken by transformers at varying terminal of 5 KT.s. No Load.

Rev. in 5 KW pri.	a	T	Energy in Pri. cct.	Amp. in Pri. cct.	PD. at Sec. terms	PD. calculated at pri. terms			
18.020	1.1236×10^{-4}	71"	199		97	808.2			
18.020		83.5	2.16		101.8	848			
18.020		93"	2.40		109.4	912			
17.820		98"	2.50		113.2	943			
18.020		108"	2.79		121.5	1012			
18.060		114.5	3.87		145.6	1213			
18.500		76	2.01		98.3	819			
18.500		40.5	107		65.5	546			
17.520		20.5	51.5		41.	342			
17.920	2.375×10^{-4}	113	48.1		40.2	335			
18.390		33	14.4		20	167			
18.130	1.1236×10^{-4}	186	4.81		179.	1490			

Observations on Condensers. 6 Dec. 1904

Sheets of linen paper 0·0015" thick were soaked in heated stearic acid. Three of such sheets were pressed together while hot to form one composite sheet thick. A condenser of five tinfoil plates each about 15 × 10 cm was made up with separations of these thick papers. The dielectric was immediately formed in two places. Submitted to 1000 volts pd and three tinfoil plates, that is ═══, six linen leaves to each separation, making a condenser of about 0·0017 ϕ the p.d. of 1000 volts alternating was readily sustained, and maintained during

The zinc air condenser exposing 930 sq. cms. at 0·097 cms. separation was subjected to $\frac{1000}{1+8} \times 113 = 9442$ volts alternating directly at its terminals without disruption.

Measurements of Specific Inductive Capacity

Sperm oil. 930·25 × 0·098 68 divs. with $\frac{126 \times 68}{2\cdot5} = 312$ volts × $\frac{1}{10}$ = 52 volt

Constants of instrument $\frac{1}{10}$ M.F.C. or 0·144 volt through 305,000 ω = 50 divs.

126 volts air condenser 928 × 0·097 = 27·5 divs

∴ 1 div = $9\cdot44 \times 10^{-9}$ amps

68 " = 642×10^{-7} "

R = $8\cdot1 \times 10^{7}$ ohms.

ρ = 769×10^{14}

$\frac{4\cdot95}{930\cdot25} = 1\cdot054 \times 10^{-4}$

$\frac{930\cdot25}{0\cdot098} = 9\cdot487 \times 10^{3}$

Bay rum cold 930·× 0·098 89·6 divs. with 104 volts. after 30 secs 79 divs

Same condenser 923 × 0·097 66·8 " " 312 "

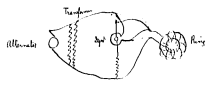
∴ Sp. I. C. = 4·0

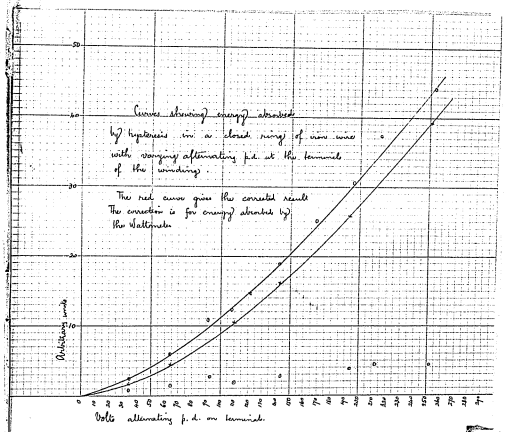
Crude ozokerite cold 930 × 0·098 109 divs. with 312 volts after 30 secs = 91 divs.

with separation 0·098 = 175·7 " "

Δ Sp. I. C. = 2·63 probably as little greater than

this as the upper plate was found to be not in contact with the wax over about ¼th of the surface.


Transformer
Alternator
Ring


Curves showing energy absorbed
by hysteresis in a closed ring of iron wire
with varying alternating p.d. at the terminals
of the winding.
The red curve gives the corrected result
The correction is for energy absorbed by
the Voltmeter
Watts energy units
Volts alternating p.d. on terminals

Measurement of Hysteresis in Iron Wire Ring 31st Dec. 91.

The particulars of this ring are recorded on page 49.
The resistance of the two primaries in series = 5.8 ω.
The alternator was employed to excite in transformers (100 ℓ); and its secondary was led through the fixed Hedderwick Dynamometer to the ring. The suspended coil was joined across the ring terminals through resistance.

All taken with coil #11

No of Obs.	Resistance excl. coil.	T	RT	R	Watts in coil:	Fd. at terminals volts			Revolutions
1	1986	123·5	2·453 × 3/10			34·5			
2	1986	40·5	0·804			34·9			Ring + Dyna.
3	3825	155·5	5·948			63·5			Dyna.
4	3825	36	1·377			64·0			Ring + Dyna.
5	3825	282·5	10·805			91·7			Dyna.
6	3825	17	2·648			92·4			Ring + Dyna.
7	7850	24	1·884			110·0			Dyna.
8	7850	155	12·168			107·9			"
9	7850	186	14·601			122·3			Ring + Dyna.
10	9990	190	18·901			143·1			Ring + Dyn.
11	9990	26	2·577			143·9			" " "
12	10,020	250·5	25·10			168·6			Dyna.
13	13,115	237	31·082			196·3			Ring + Dyna.
14	13,115	102·5	13·443			196·3			" " "
15	13,115	29	3·803			198·4			Dyna + Watts
16	13,000	287·5	37·375			215·6			Dyna.
17	13,000	34·5	4·485			213·8			Ring + Dyna.
18	13,115	224·5	44·291			253·6			Dyna.
19	13,115	24	4·318			251·7			Ring + Dyna.
									Dyna.

Kennelly Notebook #6

This notebook covers the period January-December 1892. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, cable and cable insulation, batteries, and dynamos. In addition, there are extensive notes and design drawings relating to motors for phonographs, rock drills, and fans, including an alternating current fan motor design. Also included are notes regarding the alternating current electric power system in Newark, N.J., the electromagnetic properties of iron and nickel, physiological experiments on the effect of electric current on muscle action and blood flow, along with theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "VI" and" 1892." The book contains 161 numbered pages. Some pages were removed before the book was paginated. Numerous graphs, photographs, blueprints, and other items have been pasted into the book.

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A-5931-6

No. VI.

Record Book

of

Observations, Calculations, and Data

compiled in the Galvanometer Building

Edison Laboratory, Orange N.J.

commenced 1st January 1892.

completed 2nd December 1892.

Specific Inductive Capacity Measurements.

Jan: 20th Air condenser standard zinc plates. 922·6 sq cms 0·098 apart.
600 ÷ 2 volts = 67·2 divs.

Condenser with iron plates, preparation of stearic acid containing 2½ % of $Pb\,Br_2$, resulting in a small admixture of lead stearate
930·3 sq cms 0·098 50 volts 84·5 divs. 4 divs: leakage.

S. I. Capy $\frac{6 \times 84{\cdot}5}{67{\cdot}2}$ = 7·5.

It was found on separating the plates that much of the surfaces were left uncovered by the stearate, which had cooled too quickly. The real capacity would therefore probably have been greater than the above observation showed.

Japan wax. 210 divs: 300 volts ½ div. leakage
Capacity $\frac{210}{68}$ = 3·09.

Jan: 4th Stearic acid fairly pure
Leakage 7 divs 300 volts.
Air condenser 922·6 × 0·098 300 volts 68·5 divs.
Iron " 930·3 × 0·098 50 volts 44·75
Sp. I. K = 3·92

N. B. The stearic acid tested some days previously (17th Dec). had been boiled in a leaden kettle and was probably impure on that account. It may have contained an appreciable quantity of lead stearate.

Mixture of crude ozokerite with Kerosene oil.
Iron condenser (air) before forming 930·3 × 0·098 300 volts 109 divs
" after " " 0·173 200 " 132 "

Sp. I. K. $\frac{132}{109} \times \frac{E}{e} \times \frac{173}{98}$ = 5·34

This is a much higher value than that obtained with either Kerosene or crude ozokerite.

Constant ½ Volt. Black cell 300,000 ω 47 divs. = $\frac{1{\cdot}74 \times 10^{-1}}{3 \times 10^{5}}$ = 5·8 × 10⁻⁷ amp.
1 div: thus represents 1·234 × 10⁻⁸ amp

Res. abs: = $E/(1{\cdot}234 \times 10^{-8} \times \frac{61}{d})$ and resistivity = $1/(1{\cdot}234 \times 10^{-8}) \times \frac{E}{d} \times \frac{930}{h}$ = 1·148 ×
= $8{\cdot}104 \times 10^{7} \times 930 \frac{E}{dh}$ = $7{\cdot}537 \times 10^{10} \frac{E}{dh}$

Aniline oil. — Useless. Resistance 930 — 0·095 about 1300 ω

Camphor oil — Similarly useless.

Lead Stearate — melted, pressed overnight, and cool — useless.

Jan: 7th Turpentine — 1000/300,000 — 25 divs.

Sweet almond oil 1ω in 300,000 20 divs.

Oil of lignite 1000/300,000 8 divs.

Oil of linseed 1ω / 300,000 4 divs.

Turpentine oil monochlorhydrate bad.

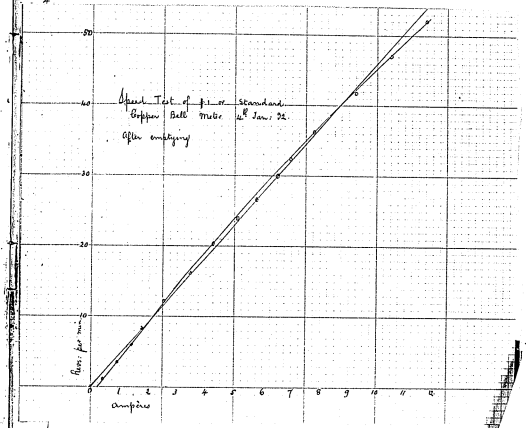
Canada balsam This measurement was not very accurate because the surface between plates were not quite filled, about 12·5 sq cms missing.

Air condenser	Zinc	101·9 divs:	250,000 / 300,000.	
Canada balsam		393·3 —	150,000 / 300,000.	Ratio 111·3 117·2
leakage		2 divs.	225,000 / 300,000	

Collection of results obtained in Spec: 2nd: Expt: Measurements

contd from p. 116

No. of Obs	Date 1899	Page	Substance	Formula	Testing time	Leakage data	Constant	Sp. I. R.	Res:	ρ
1	2nd Aug.	1	Stearic acid + Lard Stearin		300	36	$N \cdot 1.128 \times 10^{11} \frac{E}{d}$	> 7·5	6.89×10^{9}	6.9×10^{16}
2	"	1	Sperm oil		300	0·5	-	3·1	4.9×10^{10}	4.5×10^{17}
3	4th	1	Stearic acid		300	7	-	3·9	3.47×10^{9}	3.23×10^{16}
4	"	1	Oxide of zinc mixed with Resin oil		300	0·5	-	5·3	4.9×10^{11}	4.5×10^{18}
5	"	1	Anthine oil		-	-		—	1300 ω.	—
6	5th	1	Camphor oil		-	-		-	bad	
7	5th	1	Lard stearin		-	-		—	-	
8	7th	1	Turpentine					—	-	
9	"	1	Sweet almond oil					—	-	
10	"	1	Oil of lignite					—	-	
11	"	1	Oil of fennel					—	-	
12	"	1	Turpentine oil Distilled with Camphor					—	-	
13	"	1	Spermaceti				$8.77 \times 10^{3} \frac{E}{d}$	3·22		
14	8th	9	Asphalt					6·86	good	
15	"	"	Resin					-		
16	"	"	Oleic acid					2·29	very big ℓ	
17	"	"	Burgundy pitch					—	bad	
18	12th	"	Benzene					2·072	1.62×10^{16}	1.44×10^{24}
19	"	"	Burgundy pitch				$9.03 \times 10^{3} \frac{E}{d}$	—	1.28×10^{21}	
20	"	"	Resin in Benzene					3·11	3.39×10^{16}	3.22×10^{24}
21	"	"	Lignite part of 18					-	1.03×10^{16}	9.77×10^{17}
22	"	"	Balsam Copaiva					-	2.22×10^{16}	2.11×10^{24}
23	"	"	Commercial oil					-	—	—
24	"	"	Benzole (Benzene)					-	1.39×10^{15}	1.32×10^{23}
25	"	"	Oil of sweet bay					2·65	6.06×10^{16}	1.67×10^{24}


Speed Test of p.c. or standard
Boppse Bell Motor 2nd Jan: 22.
After emitging
revs. per min.
ampère
0
1
2
3
4
5
6
7
8
9
10
11
12
10
20
30
40
50

Tests of Copper Bell Meter 4th January 92.

No. 1. or standard.

The instrument was emptied of mercury, the bell removed, and then set up afresh. Paraffin oil (sp.) was poured on the surface of the mercury. The torques were then measured as follows:—

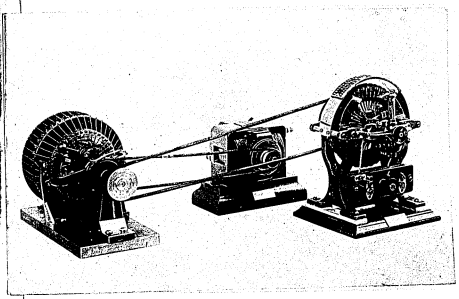
Observer A.H.

No. of Wts.	Weight of Carrier	Weights lifted	Total Wt	Rad. of Shaft	Torque com-pens.	Mean Obsvd.	Mean Amp.	Torque per amp.	Mean result
1	0·25	10	10·25	0·2425	2·691	0·39935	2·03	1·3216	
2		20	20·25		5·316	0·74·25	3·831	1·388	
3		30	30·25		7·941	1·1125	5·74·1	1·383	
4		40	40·25		10·57	1·5025	7·753	1·363	
5		50	50·25		13·19	1·835	9·467	1·393	1·371 ± 0·03
		1·50	1·75	0·	0·445	0	0		

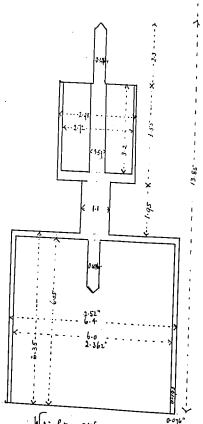
The speed was then measured as follows:—

Observer A.H.

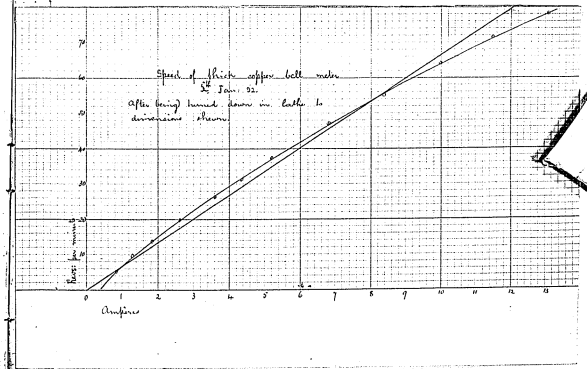
Lamps	Obsvd.	Amp.	Revs.	Time; secs.	Revs. per min.	Revs. per min per amp	Revs. per min per amp. after correction	
1	0·0744	0·382	2·	117·5	1·02	2·67	2·67	
2	1·166	0·827	4	66·4	3·61	4·21	4·21	
3	0·257	1·326	6	59·2	6·08	4·59	4·59	
4	0·346	1·785	9	65	8·31	4·65	4·65	
5	0·500	2·581	12	59·2	12·16	4·71	4·71	
6	0·673	3·473	16	58·8	16·3	4·69	4·69	
7	0·830	4·283	21	62	20·3	4·74	4·74	
8	0·985	5·083	24	60·2	23·9	4·70	4·70	
9	1·107	5·712	27	60·6	26·7	4·68	4·68	
10	1·258	6·491	30	60	30·0	4·62	4·62	
11	1·346	6·945	32	59·6	32·2	4·64	4·64	
12	1·520	7·843	34	56·4	36·2	4·62	4·62	
13	1·79	9·24	42	60·2	41·9	4·54	4·54	
14	2·04	10·53	47	60	47·	4·47	4·47	
15	2·28	11·76	52	60	52·	4·42	4·42	



Full-sized section of Rhodes belt.



Weight 376 grs.



Test of a small model speed-controlled motor 4th Jan. 92.

Two pacinotti-toothed gramme-ring armatures were taken from two small Edison ½ H.P. motors. One of these was fixed in the vertical plane, while the other was mounted on a shaft immediately by its side and allowed to turn closely adjacent to it. On a sleeve over this armature shaft, were fixed two pairs of brushes, one pair running on a commutator for the armature and the other at right angles running on the commutator. The sleeve and brushes were driven by a small Perret motor, and 2 amp. in the field circuit, running about 500 rev. per minute. The emf generated by the armatures (stationary) was about 2 volts. On closing the armature circuit the armatures began to revolve until its speed was nearly equal to that of the brushes. On connecting the armature circuit through a few lamps in the mains, the speed of the armatures could be regulated from almost zero to full speed by altering the speed of the auxiliary Perret motor driving the brushes. The torque exerted by the motor taken as a whole machine was small, owing to the small size and the inconvenient method of assembling it, with armatures and field side by side. Also when the armatures was allowed to stop, a jerk was needed as an effort to start it, owing to the Pacinotti teeth all facing each other. Machine preserved.

Tests of Standard Coppon Bell meter 4th Jan. 92.

The bell was removed, and the magnets were stuck with a mallet a number of times with as much severity as they could fairly stand mechanically. The bells was then replaced and a series of torque measurements made.

No. of Obs	Weight of Carriage	Weight Lifted	Total weight	Rad. of Shaft	Torque cm-gms.	Mean Obsvd. amp.	Mean amp.	Torque per amp.	Mean result
1	0·25	10 g.	10·25	0·2625	2·691	0·392	2·023	1·330	
2		20	20·25		5·316	0·7465	3·852	1·380	
3		30	30·25		7·941	1·140	5·882	1·350	
4		40	40·25		10·566	1·4675	7·572	1·395	
5		50	50·25		13·191	1·8475	9·523	1·384	1·388±·001
6		5	5·25		1·377	0	0	0	

Test was next made with the thick copper bell at standard torque (1·398)

Obs	Lamps	Obsvd.	Amp.	Res.	Time	Rev. per min.	R.p.m. per amp.	
1	2	0·161	0·831	·6	60·2	5·28	6·35	
2	3	0·254	1·306	10	61·2	9·80	7·5	
3	4	0·350	1·801	14	61·0	13·77	7·65	
4	6	0·507	2·636	21	63·8	19·75	7·49	
5	8	0·692	3·571	27	61·8	26·23	7·35	
6	10	0·862	4·345	32	60·4	31·79	7·32	
7	12	1·022	5·276	39	62·8	37·26	7·06	
8	16	1·32	6·811	46	59·4	46·5	6·83	
9	20	1·62	8·359	55	60	55	6·58	
10	24	1·94	10·01	64	-	64	6·40	
11	28	2·23	11·51	71·5	-	71·5	6·21	
12	32	2·54	13·11	78·5	-	78·5	5·99	

Local Action Test of Edison-Lalande Cells

Jan. 6th 32.

Three Edison-Lalande cells of different sizes in porcelain jars were set up at the same time as three Lalande cells from Trances in glass jars. The zinc plates in the former are held in position apart from the Bus. solely by the top clamps. In the French cells they are held by a rubber band encircling zincs and CuOs against tiny hard rubber projections. The same solution of NaHO was used for each. The same oil was used on the surface of each.

No. of cell	Weight of Zincs	Observed total loss gms	Volume of solution	Height inches	Distance Depth inches	External diameter inches	Internal Jar Tube	Diameter Bottom inches	Size of Zinc plate each Depth	Section Breadth
1)	120		580+500	5·5"	5·4"	3·75"	3·4"	3·1"	4"	× 1·5"
2) Edison-Lalande	227 / 220		2930+700	8·5"	8·0"	6·75"	6·25"	5·75"	5·1"	× 2·8"
3)	347 / 293 / 297	933	2980+80	11·25"	10·75"	8·75"	8·25"	8·0"	7·25"	× 2·75"
4)	497		720 +50	6·16"	6·0"	4·1"	3·75"	3·65"	3·7"	× 3·15"
5) Lalande cells	327 / 377	704	2680 +70	10·5"	10·1"	5·6"	5·0"	4·75"	4·8"	× 4·3"
6)	373 / 368 / 369	1120	5050 +100	12·8"	12·3"	6·5"	5·9"	5·9"	4·9"	× 4·3"

The cells were set up and left aside on open circuit, for the determination of zinc losses by local action.

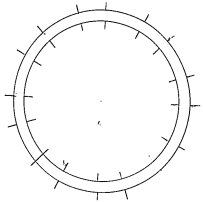
Trial of a Rock Drills operated by an motor

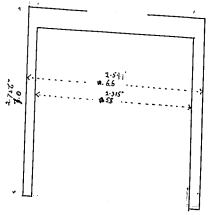
The drill is raised and lowered through a 3" stroke against a compressed spring, by a Sprague series motor geared 4:1, worked on a 500 volt circuit. When making 124 strokes per min: = 496 r.p.m. of armature, the current was 7·5 amps at 600 volts p.d. = 4·5 KW Ts. The force of the spring was 250 lbs: (including weight of rod) at full compression, and 220 lbs: in the spring. The work done at each stroke is therefore 110 × 0·25 + 30 × 0·25 = 35 ft. lbs: pearmin and 125 strokes = 4375 ft lbs: per min:

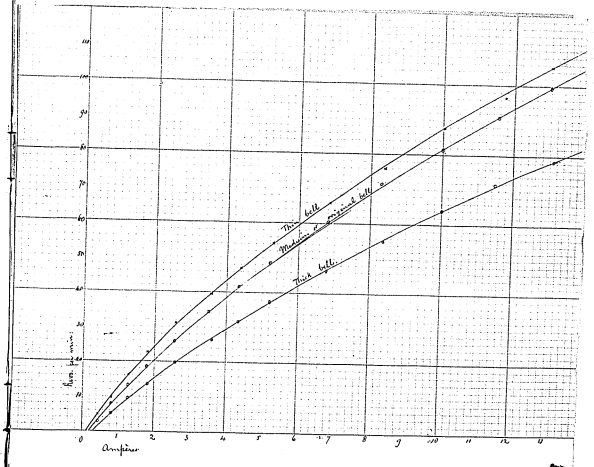
Time Record of the above Edison Lalande + Lalande Zincs

No. of Cell	Date Jan. 15	Jan. 20th 10 days	March 21st 65 days
1	120	120	101
2	227 / 220 } 447	227 / 201 } 856	227 / 201 } 956
3	347 / 293 / 297 } 933	347 / 293 / 296 } 926	347 / 293 / 297 } 907
Total	1620	1614·5	1564
%	100 / 0	99·66 / 0·34	96·3 / 3·7
4	497 497	120	broken off
5	327 / 377 } 704	327 / 376 } 703	broken off
6	373 / 368 / 369 } 1120	371·5 / 370 / 370·5 } 1117·5	360 / 353 / 343 } 1046
	2366	1990·5	1046
%		84·16 / 15·84	

The total weight of zinc for each cell is in all cases taken from summation weights, and not obtained by addition



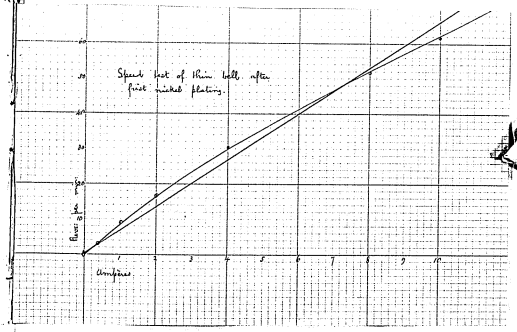

3.991"
.66
3.315"
.53
7/16"


Thick belt
Medium or ordinary belt
Thick belt
Amperes

Tests of Copper Bell Meter 6th June 91.

Three copper bells nos (1) (2) and (4) were tested in the electromagnetic field so as to obtain as nearly as possible uniform conditions.

No of No	Bell	Torque per cm	Lamps	Watts	amps	Revs. per min	R.p.m. per amp
1	Thick # 4	1.395	1			0	
2			2	0.161	0.831	5.28	6.35
3			3	0.254	1.306	9.80	7.50
4			4	0.350	1.801	13.77	7.65
5			6	0.507	2.636	19.75	7.49
6			8	0.692	3.571	26.23	7.35
7			10	0.842	4.345	31.79	7.32
8			12	1.022	5.274	37.26	7.06
9			16	1.32	6.811	46.5	6.83
10			20	1.62	8.359	55.	6.58
11			24	1.94	10.01	64.	6.40
12			28	2.33	11.51	71.5	6.21
13			32	2.54	13.11	78.5	5.99
1	Thin # 2	1.395	1	0.089	0.459	5.02	10.94
2			2	0.161	0.831	9.90	11.91
3			3	0.252	1.3	16.7	12.82
4			4	0.350	1.806	22.8	12.62
5			6	0.507	2.616	31.1	11.89
6			8	0.689	3.555	39.6	11.14
7			10	0.854	4.407	47.	10.66
8			12	1.030	5.315	54.3	10.22
9			16	1.325	6.85	66.	9.63
10			20	1.63	8.41	76.	9.04
11			24	1.95	10.06	87.5	8.70
12			28	2.28	11.76	96.5	8.21
13			32	2.53	13.05	105.5	8.09
1	Medium # 2	1.395	1	0.094	0.433	2.91	6.49
2			2	0.160	0.826	8.01	9.70
3			3	0.248	1.280	13.42	10.48
4			4	0.341	1.760	18.43	10.47
5			6	0.500	2.580	26.64	10.09
6			8	0.679	3.504	34.43	9.83
7			10	0.841	4.340	41.3	9.52
8			12	1.013	5.227	48.5	9.28
9			16	1.31	6.760	60.3	8.92
10			20	1.61	8.308	71.5	8.61
11			24	1.94	10.01	81.5	8.14
12			28	2.24	11.56	91.	7.87
13			32	2.53	13.	99.5	7.65


Speed test of Rim bolt after
first nickel plating.
Amperes

Tests of copper bell meter 7th Jany. 92.

A trial was made of supplying the current into the upper surface of the mercury instead of at the upper electrode cup. For this purpose the guard plate was removed, and a nickel-plated electrode elevated on the mercury surface. It was found that when supplied in this way the bell would rotate with the current from one lamp although it sometimes hesitated and would not start. The thin copper bell was used in its varnished state, so that the current had to pass entirely through the mercury between the bell and the outer walls. The speed of rotation for a given current was found to be reduced. The following torque measurements were made.—

10½" Std.

No. of Obs	Total weight lifted	Torque em. gms.	Ascending amp.	Descending amp.	Mean amp.	Torque per amp.	Mean
1	1.0	0.238	-	-	-	-	
2	5.25	1.249	2.369	1.781	2.075	0.602	
3	10.25	2.439	5.17	3.793	4.481	0.544	
4	15.25	3.629	7.946	5.83	6.888	0.527	
5	20.25	4.819	10.34	8.642	9.491	0.508	0.545

The torque therefore diminishes with the current when the copper bell acts only as a plant.

To cause the current to enter the copper bell, an annular portion of the upper surface was cleaned and nickel plated. An annular nickel electrode was similarly fixed into an upper wooden cover. The following measurements of torque were now made. Tem. 11°40'

No. of Obs	Weight of carriage	Weight added	Total weight lifted	Torque em. gms	Descending current	Ascending current	Mean amp	Torque per amp.		
1	0.25	10	10.25	2.439	2.374	2.348	2.361	1.033		
2		20	20.25	4.819	4.335	4.826	4.581	1.052		
3		30	30.25	7.198	7.044	7.482	7.263	0.991		
4		40	40.25	9.580	9.70	10.12	9.91	0.967		
5		50	50.25	11.96	12.13	12.77	12.45	0.961		
∞		0.25	0.5	0.119	0	0	0	0		

The following speed test was then taken.

No. of Obs.	Lamps	Obsvd.	Amp.	Time sec.	Revs.	Revs per min	Rev. min per amp.		
1	1	0.074	0.382	72.4	4	3.315	8.68		
2		0.192	1	66.6	10	9.0	9.0		
3		0.385	2	60	16.6	16.6	8.3		
4		6.776	4	"	30.2	30.2	7.55		
5		1.582	8	"	51.3	51.3	6.4		
6		1.940	10	"	61.9	61.9	6.18		

On the Cost of a Conductor required to carry 1000 H.P. at a distance of 25 miles with 7000 volts p.d. (mean) and 30% loss.

Earth return circuit. Motor efficiency 0.93. No leakage.

1000 H.P. = 746,000 watts and at motor terminals = 802 K.W.s

30% of 7000 = 2100, leaving 4900 volts and 163·7 amps: on line

2100 ÷ 163·7 = 12·83 ω. for 25 miles = 0·5132 ω per mile.

" 113,000 cir mile = 1810 lbs: per mile or $1400 per mile @ $0·22. per lb.

Facts elicited at the meeting of N. P. R. R. Officers Edison Laboratory 8th Jany. 93. (? 92 NCS)

An empty sleeping car weighs 95,000 lbs.

Large standard locomotives carry 160 lbs: of steam with cylinders 22" × 24" — 4' drivers, cost $20,000, burn 6 lbs: per H.P. per hr.

This is equivalent to a pressure of 60,800 lbs on crosshead or 30,400 lbs. at axle.

Grades on N.P.R.R. do not exceed 1% except in the mountain section.

Distance between track centres on double track roads is 13'.0".

A loaded passenger car may weigh 35,000 lbs.

No fences line the NPRR track.

A casualty occuring on a track by reason of a person crossing it may cut in enforced legal penalty or damages. This is even when the track is fenced in.

Experiments with copper bell meters. 9th Jany 92.

All three bells were coated with nickel plate over their entire external surfaces, the interior surface being varnished.

The thin bell threw made 76 r.p.m: on 10 amps: with 10 ½" in Ring. Tens: in field instead of 62 as found yesterday. The starting friction was however much increased, and this was traced to a magnetic pull on the nickel plating. Thus the starting friction with the thin copper bell was found to be 1·0 gms: at shaft radius with no magnetising current in the separately excited field. The normal field excitation raised the starting friction to 3·5 gms, and a strong field to 5.0 gms: total weight.

Capacity Tests of various compounds.

Asphalt: Poured in hot – plain mexican asphalt – Thickness of strata could not be subsequently determined – a large number of bubbles being mingled with the mass 117.25 div 250,000/300,000
Air condenser 100 " 250,000/300,000.

Spermaceti: 930·25 × 0·098 – 50,000/300,000 — 138.5
× 0·098 air 250,000/300,000 — 101 div.
Leakage 25,000/300,000 — 1 div. comm.
Capacity — 6.86

Oleic acid: 930·25 × 0·098 – 65 div: Leakage 50/300,000 –

Rosin: 930·25 × 0·240 – 250,000/300,000 — 92·75 div
× 0·098 air " " " — 102.
Leakage 92·75 / 90·75 after 60 secs = 3.30×10^{12} ω · 3.3×10^{11}
Capacity $\frac{0.240}{0.098} \times \frac{92.75}{102} = 2.23$. $\rho = 1.25 \times 10^{13}$

Rosin repeated: 930·25 × 0·21 250,000/300,000 — 117 div.
922 × 0·098 zinc air " " — 105
Leakage 117/115 after 60 secs.
Capacity $\frac{117}{105} \times \frac{0.21}{0.098} = 2.34$

Benzine: 12th Jany. $\frac{250,000}{300,000}$ 27 divs. leakage Res. 1.62×10^{14} $\rho = 1.44 \times 10^{32}$ Mean 2·29
930·25 × 0·098 250/300,000 — 223 div
× 0·098 " " — 107.6
Sp. I. K. 2·072

Burgundy Pitch: 5th Jany. 930.25 × 0.7 The Leyden could not be estimated perhaps 0·25
Cold: 250,000/300,000 — 131 divs $R = 1.28 \times 10^{34}$.
after 1 min's insulation 126 " $\rho =$

Rosin + Kerosene oil + some benzine. 209 divs = 930 × 0.098 $R = 3.39 \times 10^{12}$
Air condenser 105 $\frac{250,000}{300,000}$ $\rho = 3.22 \times 10^{13}$
Sp. I. K = 3.11

Liquid Kerosene and such Rosin as it had dissolved. $R = 1.03 \times 10^{16}$
Leakage too great for capacity obs. $\rho = 9.77 \times 10^{29}$

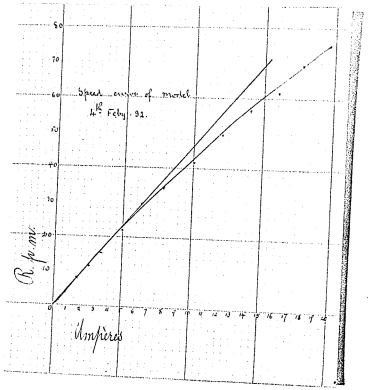
Balsam Capavia $R = 2.22 \times 10^{16}$ $\rho = 2.11 \times 10^{30}$
Capacity could not be observed.

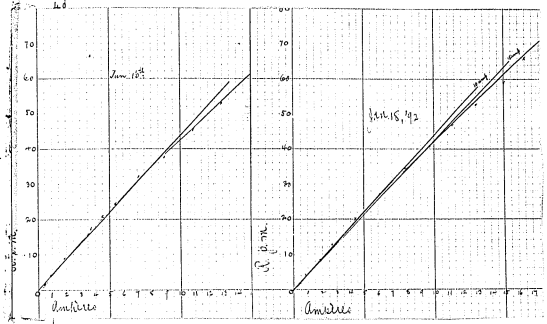
Kerosene + rosin (liquid part – solution of rosin in Kerosene oil) $R = 8.93 \times 10^{15}$ $\rho = 8.38 \times 10^{29}$
Capacity not observable

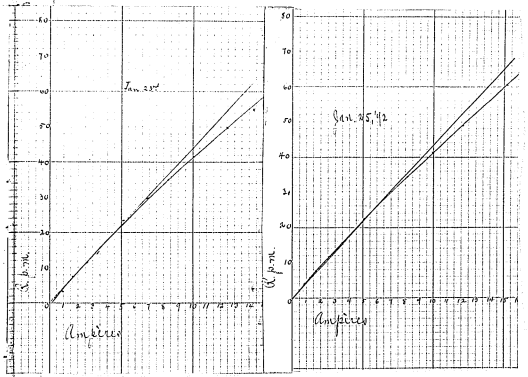
Commercial alcohol – very impure insulation

Benzole $R = 1.39 \times 10^{13}$ $\rho = 1.32 \times 10^{28}$
Capacity not observable

Oil of wood tar Air condenser 106 $\frac{250,000}{300,000}$ 930 × 0.097
Shew – with tar. 100·3 " 930 × 0·281
S. I. K. = 2·65 $R = \frac{100.3}{6.3} 1060 \omega$ $R = 5.01 \times 10^{20}$ $\rho = 1.67 \times 10^{34}$


Speed curve of motor
4th Feby. 92.
R. p. m.
Amperes


Jan. 18th
Jan. 15, 92
R. p. m.
Amperes


Jan. 22d
Jan. 25, 92
R. p. m.
Amperes

Digest of a Report from Mr C. H. Hewitt to The Engineer-in-Chief Edison General Co.

Troubles found at the Power Houses of the Erie R.R. Co. from the pitting and corrosion of their buried iron pipes that supply water. The road was originally operated by horses. When converted to an electric road, the rails were bonded with copper wire, no track wire was used, but a piece of old rail connected to track was driven into the ground every 500 or 600 feet. It was found that the iron water pipe system was carrying a share of the return current, so at some distant place, but probably 2 years ago, the ground circuit was connected to the water pipes in the station, between the feed pump and the heater. Since that time the water pipes have given continuous trouble. Specimens forwarded to the Laboratory show pitting and corrosion, such as might be caused by Electrolysis.

Measurements were made as detailed in the report going to show that of the average current supplied to the line – 220 amperes, about 90 passed into the water pipes by the pump connection in the station, and 130 by the overhead copper wire leading to the rails. The positive bus was in connection with the ground. While the pressure between the overhead trolley line and track was 493 volts, 480 were found between trolley and pipe.

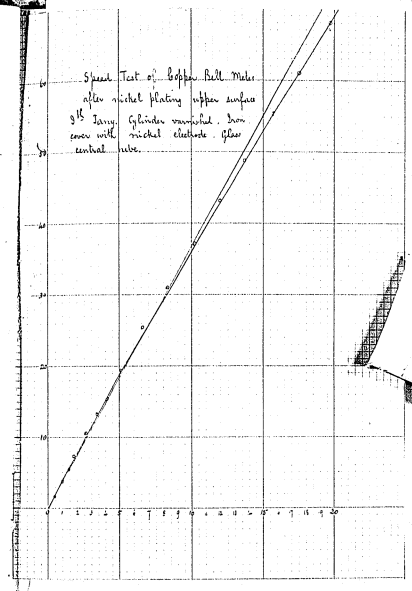
190 amperes converting Fe into Fe_2O_3 or ferric salts would consume 1390 grs daily
" " Fe_3O_4 " ferrous " " 2090 "

Tests of Copper Bell Meter after nickel plating top only. 9th Inst.

In view of the bad effects produced by nickelplating the cylinder as recorded on the preceding page, the bell was varnished on the sides but left nickelplated on the top surface and lower rim. The following torque measurements were then made in the P.M. field, with new lid and nickel electrode.

No of cells	Load	Total Wt	Rest of shaft	Torque corr. gm	Dec. current	Acc. current	Mean current	Torque per amp.	Mean
0.25	0.20	0.125	0.261	0.118					
	10	10.25		2.68	2.343	2.358	2.350	1.1140	
	20	20.25		5.286	4.469	4.567	4.518	1.170	
	30	30.25		7.896	6.512	6.914	6.713	1.176	1.160
	40	40.25		10.505	8.986	9.158	9.072	1.158	
	50	50.25		13.12	11.15	11.51	11.33	1.158	

From this series it would appear that with the top of the bell plated, the torque is nearly proportional to the current up to 12 amp.


Speed Test of Copper Bell Meter
after nickel plating copper surface
of Iron Cylinder varnished. Iron
cover with nickel electrode. Glass
central tube.

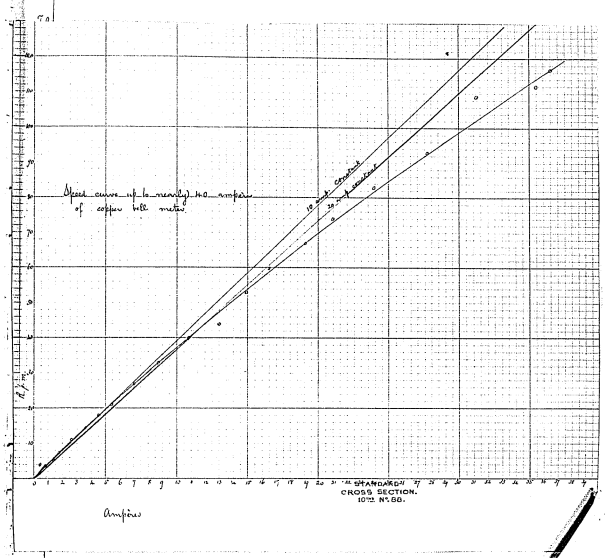
Speed Test of Copper Bell Meter with nickel plated upper surface 9th June.

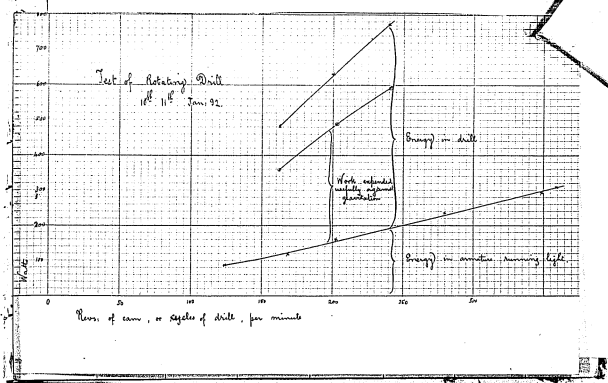
No. of Obs	Lamps.	Obsvd.	Amps.	Revs.	Time	R. p.m.	Rpm p. amp
1	1	0.893	0.480	2.0	66.8	1.796	3.74
2	2	1.193	0.944	4.0	62.4	3.846	4.073
3	3	0.260	1.342	6.0	65.8	5.471	4.077
4	4	0.341	1.76	8.0	66.6	7.208	4.096
5	6	0.509	2.627	11.0	63.2	10.444	3.975
6	8	0.669	3.350	14.0	63.6	13.21	3.943
7	10	0.813	4.196	16.0	58.6	16.38	3.904
8	12	0.981	5.063	19.4	60	19.4	3.832
9	16	1.283	6.62	25.3	-	25.3	3.822
10	20	1.604	8.277	31.0	-	31.0	3.745
11	25	1.980	10.22	37.0	-	37.0	3.620
12	30	2.310	11.92	43.2	-	43.2	3.625
13	35	2.65	13.67	48.9	-	48.9	3.577
14	40	3.04	15.69	55.3	-	55.3	3.524
15	45	3.40	17.55	61.0	-	61.0	3.476
16	50	3.82	19.71	68.0	-	68.0	3.450

Particulars of a proposed Electric Freight Railroad from Anaconda to Butte Mt.

The length of line would be 28 miles. There would be water at Anaconda, but only a small quantity at Butte. Copper mines are situated at Butte, and the ore would have to be carried over the line to the works at Anaconda where it is treated electrolytically. From 2200 to 3500 tons of ore would be hauled per diem, up a gradient of 0.3% for 22 miles. There is a steeper grade of 1% and even 1.5% at terminus, but the train could be broken for this. Coal – clinker coal – cost $4.00 ton per ton.

The only water power available would be about 75 HP. flow from the Anaconda Works.


Speed curve of 10 ampere of copper volt meter
15 ft. Standard
25 ft. Standard
STANDARD CROSS SECTION. 10"22 N°.80.
Amperes


Test of Rotating Drill
16th 17th Jan. 92.
Energy in drill
Work calculated usually required for drill
Energy in armature running light
Revs. of cam, = cycles of drill, per minute

Speed Test of Crapper Bell Motor 11th Jan: 92.

The following series was taken about 36 hours later than that on the preceding page:-

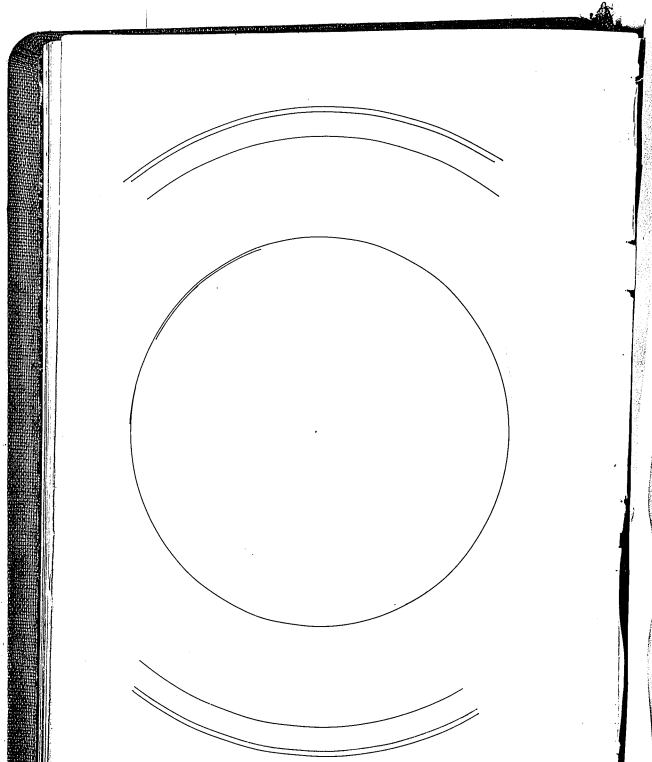
No.	Lamps	Watts	Amps.	Revs.	Time R/minute	R/p/w	R/p/w per amp.
					Secs.		
1	1	0·075	0·337	2	75·5	2·649 1·59	4·10
2	2	0·160	0·825	4	68·5	5·84 3·50	4·24
3	3	0·260	1·341	6	64·0	9·37 5·62	4·19
4	4	0·340	1·755	8	65·0	12·30 7·38	4·21
5	6	0·507	2·616	12	66·2	18·15 10·9	4·16
6	9	0·696	3·591	15	63·3	23·7 14·22	3·96
7	10	0·873	4·504	20	67·3	29·76 17·86	3·97
8	12	1·052	5·365	21	60	21·0	3·91
9	16	1·358	7·006	27·1	"	27·1	3·87
10	20	1·690	8·720	33	"	33·	3·79
11	25	2·056	10·76	39·8	"	39·8	3·70
12	30	2·52	13·0	44·0	"	44·	3·38
13	35	2·879	14·86	53·2	"	53·2	3·58
14	40	3·200	16·51	59·7	"	59·7	3·62
15	45	3·70	19·09	67·0	"	67·0	3·51
16	50	4·08	21·05	74·0	"	74·0	3·52
17	60	4·64	23·94	83·2	"	83·2	3·48
18	70	5·36	27·66	92·8	"	92·8	3·36
19	80	6·04	31·17	109·0	"	109·0	3·50
20	90	6·88	35·50	112·0	"	112·0	3·16
21	100	7·08	36·54	117·0	"	117·0	3·20
22							

Test of Cam Electric Rock Drills.

3 H.P. Spragues motor is geared 4:1 to a Rock-Drill weighing about 60 lbs. A cam on the gear-wheel lifts the drill rod 3" against the pressure of a spiral spring that it compresses. The cam on slipping allows the rod to descend under the accelerative forces of gravitation and spring. Two springs were used and following observations made:-

Motor fields separately excited

No.	Work	Revs per min.	Volts at motor brushes	Amperes in armature	Energy in Motor Watts	Work done against gravity Watts	Efficiency
1	Disconnected * averaging many numbers	124	36	2·4	86		
2		168	49	2·45	120		
3		202	65	2·5	162		
4		280	84	2·8	235		
5		348	98	3·0	294		
6		360	102	3·0	306		
7		460	121	3·2	387		
8	Drilling 250 strokes	183	53	8	424 284		
9	" 300 "	162	48	10	480 370	240	0·65
10	" " "	200	57·5	11	682 462	330	0·68
11	" " "	240	67	11·5	771 580	400	0·69
12							



4333.5 degree one
867 - - at load

0.828 w

48 wire passages

$\frac{0.042}{0.828} = 0.05$ amp - 0.005 I

$48 \times 0.005 \times \phi \times 1.4 = 867$

0.24
1.4
96
24
.336

$0.336\,\phi = 867$

$\phi = \frac{867}{0.336} = 2500$

1950

2.7 | 2500 | q.

2500×0.05

12.5

Outline of Magnetic circuit for a Torque Regulating Motor to be constructed. 12th Jan: 92.

The new ℔ 16 S.C. armature there are 8·6 ω of ℔ 14 B.S. wire or 43 lbs. which 200 Ohs. of wire are on the field. There are 70 slots on the surface and 2 windings in each slot. There will be 2440 commutator bars for the fields, and 60 slots allowing 4 windings in each slot. Each walls to be of the same thickness as at present, but 2·5 times the space has to be allowed for in each boxes $2\cdot5 \times \frac{13}{576} = \frac{203}{576}$ lb sq. in. 0·352.

The diameter of polar bore will be 18·4". Allowing 0·15" for lids leaves 18·6" diam: or 58·42" = 0·973" per slot. 4 walls 0·472 gives 0·50" for the thickness. = 0·085" deep.

The following are the proposed dimensions:-

Diam: of armature	18·25"
Clearance	0·075"
Diam: of polar bore	18·40"
Depth of Lid	0·15"
Diam: of lid circle	18·70"
Depth of bore	1·085"
Diameter of brace circle	20·87"
Thickness of field wire	3·2"
Ext: Diam: of field	27·27"
Breadth of box (rectangular)	0·5"
Breadth of wall (min:)	0·47"

Test of 5 KWT (100 : 2) Transformer 13th Jan: 92.

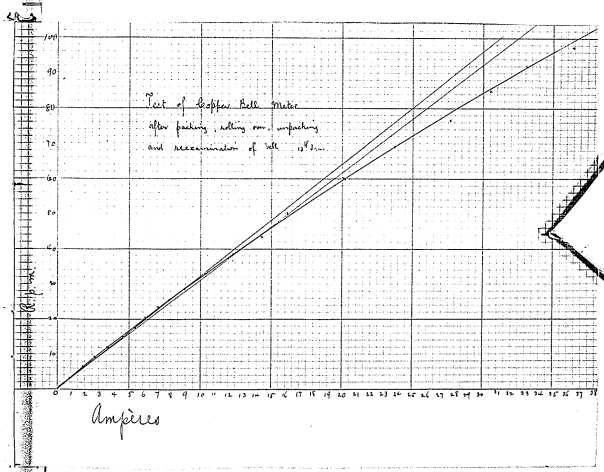
The transformer was set in its shell, and kept on full load (100 ℔ with 12½ volts at secondary terminals commencing at 2h·00 on the 13th Jan: .

The temp: on the shell was observed at hourly intervals as follows:-

No. of Obs.	Time	Hrs. from Start	Temp: on shell °F	Elevation °C	Elevation per hour °C	Time Hrs. from start	Temp: from start °F	Temp: on shell °F	Elevation Temp: Elevation
1	2h·00	0	60° 65°			12·0	168°	76·6	61° +2
2	1·00		91 33	18	18	13·0	169	76°	61° 0
3	2·0		110 43	26	10	14·0	170	77°	62° +1
4	3·0		123 50·5	33·5	9·5	15·0	170	77°	62° +0
5	4·0		138 59	44	8·5	16·0	170	77°	62° 0
6	5·0		148 62·7	47·7	3·7	17·0	169	76·5	61·5 -0·5
7	6·0		153 67	52·	4·3	18·0	168	76°	61 -0·5
8	7·0		162 72	57	5·0	19·0	166	75°	60 -1
9	8·0		168 76	61°	4·0	20·0	164	73°	58° -2
10	9·00		169 69	51°	-7	21·0	166	75°	60 +2
11	10·0		164 73°	58°	+4	22·0	166	75°	60 0
12	11·0		166 74°	59	+1	23·			

The temp: elevations in the above table are somewhat uncertain, as the temp: of the surrounding air was not observed.

Res: of primary @ 22° = 0·829 = see: 0·062.
@ 22·volt: = 1·194 0·073.
Ratio = 1·4440
Temp: Elevation = 44 / 0·388 = 113° C. = 125° C. inferred temp: of wire.


Test of Copper Bell Meter
after packing, rolling over, unpacking
and reexamination of Oct 13th 1...
Amperes

Test of Copper-Ball Meter 11th Jany. 92. (11)

The permanent magnet meter was sealed with a spring stopper, nearly full of mercury. In this condition, with the dial plate and yoke removed, it was packed in a double box, which was then rolled over falling from side to side about one hundred times along the floor of a corridor. It was then unpacked and found to be in good order with none of the mercury dislodged. The copper ball was examined, removed, and replaced. The following measurements were made of its torque and speed.

No of Obs	Rad. of Stop	Weight of Sliding	Weight Effd	Total weight	Mean Torque	Mean Current	Torque per amp	Mean
1	0.26	1.27	0·1	0·37	0·036	~~2·774~~ 0	0·	
2			10	10·27	2·67	2·784	0·959	
3			20	20·27	5·27	5·29	0·996	
4			30	30·27	7·87	~~7·98~~ 7·98	0·990	0·975
5			40	40·27	10·47	10·78	0·971	
6			50	50·27	13·07	13·60	0·961	

It is therefore evident that either the shattering that has been given to the mercury or else the removal and replacing of the cup had altered the torque per amp. by probably affecting the rest of the nickel plated surface.

No Obs.	Lamps	Ohms	Amps	Time	Revs	Revs per min	Revs per min ÷ Amps	
1	1	0·0792	0·475	83	2	1·1446	3·0144	
2	2	0·173	0·893	56	3	3·214	3·599	
3	4	0·353	1·821	64	7	6·562	3·603	
4	6	0·518	2·673	65	10	9·23	3·453	
5	8	0·691	3·566	65	13	12·0	3·365	
6	10	0·886	4·572	67	17	15·22	3·329	
7	12	1·044	5·387	65	19	17·54	3·256	
8	14	1·194	6·161	64	22	20·62	3·347	
9	16	1·380	7·121	60	23·5	23·5	3·300	
10	18	1·532	7·905	"	25·7	25·7	3·251	
11	20	1·704	8·793	"	28·4	28·4	3·23	
12	25	2·12	10·42	"	32·8	32·8	3·148	
13	30	2·29	12·33	"	38·5	38·5	3·122	
14	35	2·77	14·29	"	43·5	43·5	3·044	
15	40	3·14	16·20	"	50·0	50·0	3·086	
16	50	3·92	20·23	"	60	60·	2·966	
17	60	4·60	23·74	"	69.	69.	2·907	
18	70	5·36	27·66	"	76·5	76·5	2·766	
19	80	5·91	30·50	"	85	85	2·787	
20	90	6·42	33·13	"	92	92.	2·777	
21	100	7·05	36·38	"	97·3	97·3	2·675	

Test of Brooker-Wheeler arc light circuit motor fitted with copper shell 2 June 14

The G.W. series motor about ½ H.P. had a copper cylinder inserted between field pole and armature in the air gap. The dimensions of the shell are 0.029 Thickness. Length 5.0. Ext. diam. 3.6. Int. diam. 3.242.

The field of the motor was separately excited, and the armature operated from the 10 volt circuit. The copper shell was free to revolve with a pulley attached, on the armature shaft. A leather cord ran from the shell pulley to a small countershaft pulley which countershaft was coupled by spring with a 1/10 H.P. Perret Motor in the floating dynamometer.

The G.W. Motor terminal 0.3 ohms ran at an observed speed, and the energy at brushes was noted. The torques and speed of the Perret driven by the shell were also observed. This gave the proportion of work available at the shell to the work absorbed by the Gramme motor.

No. of Obs.	Current in Motor	G.W. armt. Amp.	Volts at brushes	Activity in watts	Speed of G.W. armt. r.p.m.	Res. of armt.	Activity lost in armt. watts	Efficiency
1	1.19	6.14	10.6	65.08	2120	0.3	11.1	5.4
2	1.225	6.32	10.6	67.	1940		12.0	55.
3	1.250	6.45	10.6	68.37	1580		13.5	55.8

Speed of Perret motor r.p.m.	Balance		Moment	6.165 × Moment	Activity in Perret watts			
	r.p.s.	@						
11.	50	1.6	80	4.93×10^5	0.54			
3.69	50	17.4	970	5.98×10^6	2.21			
1.76	50	20.4	1020	6.287×10^6	1.11			

No. of Obs.	Current in G.W. armt.		Volts at brushes	Activity in watts	Speed of G.W. armt. r.p.m.	Res. of armt.	Activity lost in armt. watts	Effort	
1	0.475	2.452	7.60	18.64	1160	0.3	1.80	16.94	
2	1.010	5.212	7.56	39.40	1040		8.15	31.25	
3	1.190	6.141	7.54	46.38	1025		11.31	35.0	
4	1.060	5.47	7.56	41.35	1053		9.00	32.35	
5	1.120	5.779	7.56	42.55	1040		10.02	32.53	
6	1.150	5.935	7.49	44.46	1020		10.57	33.9	

The test was repeated on the 18th January with more numerous observations as follows:-

Speed of motor r.p.m.	Speed of Perret r.p.s.	Balance		Moment	6.162 × Moment	Activity in Perret watts			Condition
0	-	-	-	-	-	-			Running light
-	-	-	-	-	-	-			Belt slips, no load on motor
-	-	-	-	-	-	-			Belt slips, no load on motor, Perret light
324	5.4	50	@ 3.8	1908	1.171×10^6	0.63			- fully on
176	2.93	50	@ 17.6	880	5.425 "	1.57			" " "
99	1.65	50	@ 23.8	1190	7.336 "	1.21			" " "

1000 weight 16,920 lbs. reactz 0·0574 = cost = 1·325 per mile $ 10,230

Estimate for Power Transmission. 18th Jany. 92.

(12)

1st 1680 HP. delivered at turbine main-shafts.
Transmission is desired to a distance of 20 miles, employing 2 lbs. of underground conduit at each end followed by overhead wires.

1680 HP. = 1253 KWTs.

Efficiency of generator 0·92
Power at generator terminals = 1153 KWTs. Terminal pressure 7000 volts, γ = 165
Allowing loss in line at 10% or 700 volts or higher :—

Available electricity @ 0·92	Effcy of KWTs.	% Drop	Actual drop	Res:	Res. per mile 39 mile	B. Mls.	Cost per mile @ £25	Total cost.	Pressure at Generating end	Energy KWTs.
1153	1010	0·146	5	350	2·12 =	0·060056	947,600	$ 4,010	$ 140,400 / 132,000	6650
1133	957	0·944	10	700	4·24	0·12.11	447,800	2005	70,200 / 62,110	6300
1126	903	0·841	15	1050	6·365	0·1816	315,870	1336	46,760 / 41,400	5950
1114	850	0·691	20	1400	8·4814	0·24224	236,900	1003	35,100 / 31,080	5600
1088	797	0·618	25	1750	10·61	0·3031	189,520	802	28,090 / 24,860	5250
1063	744	0·539	30	2100	12·73	0·3636	157,900	668	23,380 / 20,700	4900

The cost of machinery to the public is 40% of $60 per KWT. or $36 per KWT.

	5% drop in line 0·806	10% drop 0·764	15% drop 0·721	20% drop 0·679	25% drop 0·636	30% drop 0·594
Cost of 1250 KWTs. Generators	45,000	45,000	45,000	45,000	45,000	45,000
Cost of conductors 0·8 sq. inches	18,000	14,000	14,000	14,000	14,000	14,000
Cost of 40 miles Cable.	79,000	53,000	22,000	18,000	16,000	13,000
Cost of 31 - medium copper	124,300	62,130	41,400	31,050	24,840	20,700
- - Motors	39,530	37,400	35,300	33,300	31,200	29,180
Total cost.	292,830	191,530	157,700	141,350	131,040	121,800
Cost per KWT added	$ 290	$ 200	$ 170.60	$ 146.50	$ 140.50	$ 163.60
Cost per HP.	$ 209	$ 142.20	$ 120.30	$ 104.10	$ 103.70	$ 122.10

2nd 4800 HP. transmitted 50 miles distance. 4800 HP at Turbine shafts
4800 HP. = 3580 KWTs. Efficiency of generators 0·92 = 3293 KWTs. @ 700 = 470

% Drop	Actual Drop	Res:	Res. per mile for 39 miles	B. Mls.	Cost per mile @ £25	Total cost 51 miles	Pressure at receiving end	Energy at turbine	Availably energy @ 0·933	Generl. Efficiency	Available Energy in HP.
5	350	0·74446	0·13754	4,244,000	$ 179,340	9,915,000	6650	3426	2876	0·803	3855
10	700	1·1490	0·02708	2,120,000	8,968	457,500	6300	2962	2725	0·761	3652
15	1050	2·2334	0·014861	1,413,000	5,976	304,800	5950	2798	2574	0·719	3450
20	1400	2·978	0·0284113	1,060,000	4,493	229,200	5600	2633	2422	0·677	3246
25	1750	3·7246	0·06767	848,000	3,588	183,000	5250	2468	2271	0·634	3042
30	2100	4·4688	0·08121	706,700	3,036	154,800	4900	2304	2120	0·592	2842

	5% drop in line 0·806	10% drop in line 0·764	15% drop 0·721	20% drop 0·679	25% drop 0·636	30% drop 0·594
Cost of 3293 KWTs. in generators	$ 118,600	118,600	118600	118,600	118600	118600
Cost of poles 825 miles @ $30	24,000	24,000	24,000	24,000	24,000	24,000
Cost of 40 miles cable	220,000	110,000	88,000	60,000	55,400	44,400
Cost of 51 - overhead conductor	91,000	457,800	304,800	228,600	183,000	175,300
- Motors	112,600	106,700	100,700	94,800	88,840	82,960
	1390,200	816,800	633,900	526,100	469,840	445,760
Cost per KWT added	$ 483.40	$ 293.80	$ 216	$ 247.30	$ 246.90	$ 210.30
- HP. -	$ 289.70	$ 223.70	$ 183.60	$ 162.1	$ 154.40	$ 156.90

1st Model

Mains ₰ 24 B.W.G. hard drawn tinned copper wire doubled 4.811 c. mils each = 9.62 c. mils $\frac{0.0370}{2}$ = per foot = 0.0185 Ω representing 7.33×10^{-5} Ω per foot on actual plant.

% Drop at { A 5.92 X 7.99 ; B 5.94 Z 6.30 ; Feeder ends { C 6.11 ; D 5.23 } } Res. between two bars by bridge 0.1407 Ω. Resistance of Lamps if no mains are inserted 0.3994 Ω. Calculated from Loads. Actual 0.26

262.81 amps. through lamps representing 1295 16 c.p. lamps on system.

2nd Model. Same mains and feeders but with different load.

% Drop at { A 10.67 X 12.55 ; B 9.82 Z 9.5 ; C 11.22 ; D 10.82 } Actual 11.69

502.41 amps. through lamps representing 2475 16 c.p. lamps on system.

Calculation of the Drop in Pressure over the Trenton 1886 System. (7)

19th Jany.

A calculation has already been made of this system in Book II at page 149. More complete data is however now supplied both as to conductors and as to the situation of the loads upon them. The following tables gives the feeders and mains.

Feeder	Length feet	Gauge wire all B.W.G.	Circular mils	R. per foot	Load per foot	Total res.	% Conductivity last res. allowed	Loss of Pressure at 660 Volts
A	6314	₰ 6 ; ₰ 10 ; ₰ 10	41,740 ; 10,380 ; 10,380 ; 62,480	1.231×10^{-4}	3873 ; 2958 ; 1692 ; 8523	0.07804 Ω	97%	₰ 3
B	695	₰ 6 ; ₰ 10 ; ₰ 10	41,740 ; 10,380 ; 10,380 ; 62,500	1.447×10^{-4}	3873 ; 1692 ; 1692 ; 7257	0.1041 Ω	97%	₰ 3
C	220	₰ 12	11,881	8.924×10^{-4}	1117	0.1970 Ω	per c. mil	₰ 12
D	627	₰ 6 ; ₰ 8 ; ₰ 10	41,740 ; 16,510 ; 10,380 ; 68,630	1.137×10^{-4}	4266 ; 2535 ; 1692 ; 8493	0.07129 Ω	97%	₰ 4
Mains		₰ 20	1010, 1020	7.368×10^{-5}	13570			₰ 4

A map was made on the scale of 25 feet to the inch or 1/2000th natural size. The mains were layed off on this map as copper wire doubled ₰ 24 B.W.G. hard drawn offering $\frac{0.023}{2}$ Ω per foot or just 180 times the resistance of the mains in the actual plant. But this means the resistances on the model between any two points were just half what the actual resistances in Trenton must have been. The contracts to the number of 158, in evidence as having been fulfilled, were examined and the lamps summed and marked off in c.p. on each house. The current in each house was next found assuming every lamp lit by allowing 0.65 amp to each 16 c.p. 105 volt or 0.325 amp. on 3-wire 210 volts = 0.0203 amps. per c.p. The drop in the houses and house leads was neglected, and the load in amperes collected to each pole. A distinction was made however between the loads operated when the plant first started, and those assumed 3 months later.

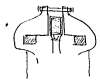
The resistances corresponding to these loads divided by two, were made up of german silver wire S.C.C. 1 paraffin waxed, and then taken connected across the mains at the proper points. Feeders of copper wire of 0.039 Ω, 0.052 Ω, 0.078 Ω and 0.036 Ω each side conductor, were connected on from the station to the proper points of the system. Two Latimer cells in series were shown connected through leads to the P.S. bus bars, and two more thick leads from these to the new potentiometer, having 510° of g.s. wire offering a res. of 7.805 Ω. The travelling contact was placed in connection with different points of the system by a stray wire through the 1000 Ω galvo. The balance gave the % drop on one side of the 3-wire system directly. After the pressure had thus been mapped out completely for the system as first started, the loads were altered to represent the conditions 3 months later, and new readings taken. Finally the mains were altered at the extremes and a third series taken, when one ₰ 24 B.W.G. of the two forming the mains was exchanged for a ₰ 26 B.W.G. = 324 + 484 = 808 c. mils representing 12,1200 c. mils which ₰ 0 B.W.G. is 0.340 and 115,600 c. mils.

If a lateral displacement took place in this armature from the centre of ¼" or 0·25 cms, it would alter the centres in ratio of 2·1 to 2·8. The effect of the field reluctance would be to alter this in ratio of 2·05 to 2·45. of the 12,100,000 C.G.S. lines issuing from each pair of like poles, 5,611,000 would enter from the far side and 6,489,000 . . . from Rep. 8 making the flux densities 4,305 and 5,070 respectively.

The stresses per sq: would be $7{\cdot}378 \times 10^5$ $10{\cdot}24 \times 10^5$
or 754 gms 1044 gms
166 . 230 lbs.

The difference in ~~pressure~~ stress = 0·664 lbs per sq: cm:
The total polar area 12,800 = 8192 lbs

Particulars of a 300-KW.T. multipolar dynamo proposed to be constructed for the N. Y. Elec. Co.



Power 300 KW.Ts.
Voltage 160
Amps. 1875.
Speed 120 r.p.m. 2 r.p.s.
Poles 10 on each side (5 H and 5 S) 20 polar faces in all.
Estimated weight 28,000 lbs.
Flux through each polar face 6,050,000
Total flux 60,500,000
Gross section of armature core 30 x 19 = 570 sq: cms.
Effective cross. section allowed 0·85 = 484 sq: cms.
Useful flux density in core 12,500
Total useful armature flux = 6,050,000
Polar surface 1280 sq: cms: on each side = 2560 sq: cms:
Air gap (entrefer) 2·25 cms. on each side
Clearance 0·6. (0·25")
External diameter of armature core 88". (223·5)
Internal . . . 64" (162·6)
Flux density in air gap 4800.
Breadth of armature core 7·5" = 19·05
Mean length of magnetic cct: in steel magnet 150 cms.
. flux density . . . . . 12,500.
. leakage allowed 0·25
Number of bars = 650 for multiple winding
Mean length of turn 42". 106·7 cms.
. cross section = . 0·16" = 103 sq: cms:
Resistance between brushes 0·00123 ω.
Drop in armature at full load = 2·34 volts.
Field spools one on each side of armature, about 9" square section
Mean turns about 48".
Mean length of one turn 170".
Brushes two sets, one to each segment.
Commutation on external surface of armature.
Surface speed of commutation 2720 ' per min:
If this armature were series wound, there would be 154 turns, with a change of shape in cross section.

From these figures the total field flux is 8,064,000 and the mean cross section of field core 640 sq: cms.

Reluct nce of field =	$\frac{150}{6440} \times 0{\cdot}0022 = 0{\cdot}0005156 \times 2 =$	103×10^{-3}
. . armatur & ½ this		0·26
. . air gap (entrefer)		7·34
		9·23

MMF necessary to force $3{\cdot}025 \times 10^4$ lines through this ckt = $27{\cdot}92 \times 10^3$ = 27920
. 22,220 A.T.

On the Cost of Transmitting 1000 HP electrically to a distance of 16 miles

Objections are raised by the intending purchaser to operating generators in series, and the highest potential that the Schenectady Works will attempt at present is 2000 volts.

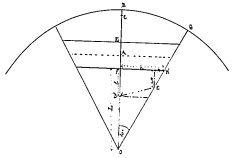
Allowing 2000 volts at motor terminals or a drop of 1000 volts.

1000 HP at Motor shafts @ 0·92 = 1087 HP. = 811 KWTs @ $60 = $ 48,660		48,660
Current at 2000 volts = 405·5 }		
Resistance of line 2·46 ω.		
If ground can be obtained allow 0·46 ω for same		
and resistance of line = 2 ω or 0·125 ω per mile		
= 475,000 c. mils. $2000 per mile 16 miles		32,000
If ground cannot be obtained, and return cct is used		
32 miles for 2·46 ω = 0·0769 ω per mile =		
750,000 c. mils $ 3,172 per mile × 32 miles =	101,504	
Generator 3000 X 405·5 = 1216·5 KWTs @ $60 =	72,990	72,990
	223,154	153,650

Weight of a brass casting made from a wooden pattern.

The pattern weighed 7 lbs 4½ oz = 7·28 lbs.
" casting " 1142 lbs.
" ratio 19·5.

Determination of the conditions for maximum winding space in a hexagonal frame armature.



In the sector of 30° BOC. OA = $\frac{3}{4}$OB, AF = AE are magnetically determined, and BC is mechanically confined. This gives AD = AC. The winding space cross section for the coil is thus $\frac{y+l}{2}(L-x)$ when $y = \frac{3}{4}L$

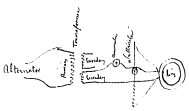
$$\text{Area} = -x^2\frac{L}{2h} + x\frac{L}{2} - \frac{yl}{2} + \frac{hl}{2}$$

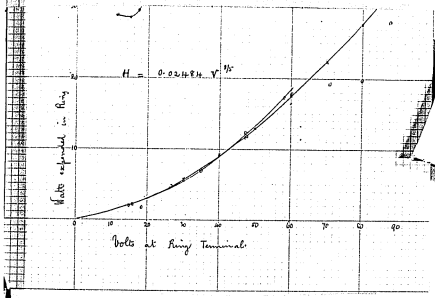
$$\frac{d(\text{area})}{dx} = -\frac{Lx}{h} + \frac{L}{2} = \frac{l}{2}$$

$$\therefore x = \frac{L-l}{2} \times \frac{h}{L}$$

$$= \frac{h}{2}\cdot\frac{L-l}{L}$$

If l is less than a certain quantity, the best value of y for a maximum area becomes greater than l


Alternator
Transformer
Rectifier
Rectifier
Ring
Collector


H = 0·02484 V^½
Volts at Ring Terminals
0
10
20
30
40
50
60
70
80
90

Hysteresis Test of Nickel Wire Ring

23rd Jan: 32.

A closed Faraday ring was formed of nickel wire diameter 0·0365 (0·0367) 0·0924. There were 570 of these turns of wire making 3·955 sq: cms, the area of each wire being 0·006934 sq: cm. The weight of the wire is 2253 gms. The int: diam: 18·5 approx. and the ext: diam: 23·5 approx; so that the diameter of the section is roughly 2·5.

The ring was wound with 700 turns of #22 B&S (0·028") in 7 layers. It was connected up through an ammeter and wattmeter with the secondary coil of a transformer and the power absorbed measured as the pressure increased. Coil #3 of the Wattmeter was used.

	Res.	α	τ	Energy in ring	Burnt	C^2R	Ohmic energy	Residual energy (Hysteresis)	Efficiency Pct.	Energy in Gas Jet
	1790	$2·375\times10^{-5}$	26·5	1·198	0				12·5	
	2310		38·5	2·11	0·1	0·01	0·033	2·077	16.	
	2260		53·5	1·80	0·1	0·01	0·033	1·767	18·5	
	1850		110·5	4·85	0·15	0·0225	0·075	4·775	26·5	
	1010		83·5	2·004	0		-	2·004	15	
	3085		98	7·18	0·25	0·0625	0·208	6·972	35	0·3
	3160		168·5	12·65	0·35	0·1225	0·407	12·243	47·6	0·7
	4560		169	18·31	0·58	0·3364	1·12	17·19	58	0·74
	4740		204	22·96	1·05	1·103	3·67	19·29	71·2	
	6740		176·5	28·26	1·60	2·56	8·51	19·75	80	
	6010		307	44·10	2·2	4·84	16·1	28·0	88	

A second ring was made up of a longer length of nickel wire (same wire) in diam: The int: diam: of the bank was 18·0, the ext: diam: 24·3 Mean diam 21·15. Mean circ: 66·45 cms. The weight of the ring was 2275 gms. The winding was 700 turns of # 21 B&S 0·032" 0·046"

There were 44160 turns of wire

The cross section of the wire = $8·442\times10^{-4}$

" " " " ring = 3·966 sq: cms.

$\phi = \frac{B\lambda}{4\pi} = \frac{1·4114\,\alpha}{700\times899·5} = \frac{1·4114\times6\times10^{-5}}{0·6227} = 2·27\,\alpha\times10^{-4}$ in the first test

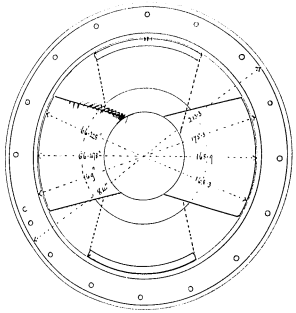
$\phi = \frac{1·4114\,\alpha}{605\times899·5} = 2627\,\alpha$ " 2nd test see p. 89.

$75·94\times3·12 = 237'$

$99·18\times1·814 = 180'$

Scale 1/20 th.

Section of 100 KWT machine in plane of revolution.



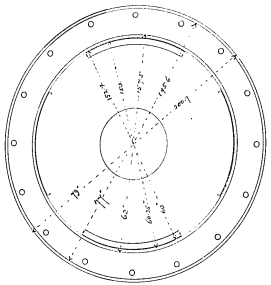
Electromagnetic Design for a generator of 100 KWTs capacity at a pressure of 10,000 volts cont:

(21)

	Type quadriplan Greenwood Rang
Power of dynamo at brushes	100 KWTs.
E.M.F of dynamo	10,000 volts at fulls load.
E.M.F allowed for	11.000 "
Current at full load	10 amperes.
Number of poles	4
Speed of revolution	172 r.p.m. = 2.867 r.p.s.
Armature useful flux	7,000,000
Number of turns	$1.1 \times 10^{10} \div (2.867 \times 7 \times 10^{6}) = 27,400$. allow to 26,304
m	0.025
Res: between brushes	25 ω.
" all round	400 ω.
Res: per turn	1.46×10^{-3} ω.
Ratio of $\frac{\text{length}}{\text{depth}}$ of core	2.5
Flux density in core	9000
Useful cross section of core	778 sq: cms.
Space factor	0.85
Actual cross section	915 sq: cms.
Depth of core	19.05 (7.5")
Breadth " "	48.03 (18.9")
Annular area	$55.21.8 - 37.9.3 = 1802.5$ sq: ins = 11630 sq: cms.
External diameter	213.3 (84") Circ. 670.25 (263.9")
Internal "	175.3 (69") " 550.7 (216.8")
Volume of core	558,700 c.c.
Effective " iron	475,000 "
Mass of iron in core	3706 kgms = 8170 lbs.
Length of one turn	56.6" (1144 cms) = 4.71'
Res: marked per foot	0.00310 ω @ 100° C. # 16 B.W.G 0.065" d.c.c. 0.078".
Circular mils	42225
" per amp.	1690
Length of wire on arm	129,100 feet.
Weight " " "	1652 lbs.
Turns per quadrant	6850 altered for convenience to 6576
Turns per layer	2185 in one circle allowing 80% space.
Layers allowed	12
Depth of winding	0.936"
Body insulation	0.2"
External insulation	0.125"
Clearance	0.125"
Entirefer	1.390" = 3.5 cms
Polar arc	60°
Polar surface	$88 \times 48 = 42224$ sq: cms
Reluctance of air gap	$2 \times 3.5 \div (9112) =$ 3.315 m.m.
Reluctance of armature	$90 \times 1.2 / 778 =$ 0.1388 m.m.
MMF for 7,000,000 lines	23200 = 18660 A.T.
Flux density in air gap	3315 useful.
Amp. turns in armature	$274,000 / 551 = 497 \div 4 = 125$
Flux density per cm sec	2614.
Number of Coutt bars	548 = 137 per quadrant
Winding	Blocks of 4 wires wide + 12 step to centre.

Electromagnetic Design for a 100-Kilowatt 10,000-volt Generator or Motor.

Power	100,000 Watts	Quadripolar Gramme Ring
P.D. at machine terminals full load	= 10,000 volts.	11,000 allowed for
Current at full load	= 10 amps.	
Number of poles	= 4	
Speed of revolution	= 286.5 r.p.m. = 4.775 r.p. sec.	
Armature useful flux	= 7,000,000	
Number of turns needed	= $1.1 \times 10^{12} \div (4.775 \times 2 \times 7.0 \times 10^6) = 16450$	
" " allowed	= 16,800.	
m	= 0.025	
Res.: between brushes	= 25 ω.	
all round armature	= 400 ω.	
Res.: per turn	= 2.381×10^{-2} ω	
Ratio of breadth to depth of core	= 2.5	
Flux density in core	= 9000	
Useful cross section of core	= 778 sq: cms.	
Space factor	= 0.85	
Actual cross-section	= 915 sq: cms.	
Depth of core	= 19.05 (7.5")	
Breadth "	= 48.03 (18.9")	
External diameter of core	= 77" (195.6) = 241.9" circ: 611.5 cms	
Internal " " "	= 157.5 (62") = 194.8" circ: 494.8 -	
annular area of core	= 4656.6 − 3019.1 = 1637.5 sq: cms. 1057 sq: ins.	
Volume of core	= 507.500 c.c.	
Volume of iron in core	= 431.500 c.c.	
Mass of iron	= 3.366 Kgms. = 7420 lbs.	
Length of one turn	= 56.6" (144) = 4'.7	
Resistance of wire per foot	= 1.005068 ω @ 100°C	
Total length of wire	= 78960'	
Diameter of wire	= 0.0505" #16 B.S. d.c.c. & 0.064"	
Number of turns in one layer	= 1575 62 × 0.8 ÷ 0.064 × 3.1416 = 24.435	
Number of turns allowed	= 2100 and 7 layers.	
Commutator blocks	= 600 or one to each 28 turns	
Armature winding	= 7 wire deep and 4 wide.	
Mean Volts per turn	= 2.62 or 73.34 per commutator block.	
Lineal miles in wire	= 2.581 or 10.32 per ampere at load.	
Weight of wire on arm.	= 617.7 lbs.	
Clearance	= 0.125"	
Internal armature winding diameter	= 60.25"	
Depth of winding	= 8 × 0.064" = 0.512"	
Winding external diameter	= 60.89"	
Thickness of body insulation	= ~~64.53~~ 0.235"	
Winding external diameter	= 61.53"	
Polar face angle	= 60°	
Polar surface	= 82.5 × 48 = 3962 sq: cms.	
Entrefer	= 1.0" = 2.54	
Magnetic circuital gap = Polar arcs	= 2 × 2.54 / 2000 = 2.54 m.m.	
Armature segment	= 0.13 m.m.	
Estimated total Sat. in ckt.	= 2.9 m.m.	
MMF for 7,000,000 CGS.	= 20,300 = 16,240 Amp Turns.	
Flux density in air	= 3500.	
Amp turns per cm: on arm.	= 42,000 / 500 = 84	
Running value	= 41.7.	



Annular area of armature	= 4971 − 3022	= 1949 sq: cms.
External surface	= 183 π × 52	= 29,000
Internal "	= 209 π × 52	= 32,670
Total "	=	61,670 sq: cms.
Energy in arm: at load	= 2.5 Kwts.	
Hysteresis	= 0.003 × 4 × 4318 × 10^8 × $(9.0 \times 10^3)^{1.6} \times 10^7$	= 1.10 × 10^4
	= 1.10 Kwts.	
Total energy lost	= 3.60 "	
Energy per sq: cms:	= 1/17	= 0.05861
Sq: cms: per watt	= 17.06	

Tests taken at Schenectady 14th January on the Static Capacity of a certain sample of Cable.

1# = wire cable, each wire 0·0403" (0·1023) # 18 B.W.G., insulated with dry paper to a thickness of 0·125" (0·3175").

Length 4·70 feet by rotometer.

Capacity by direct deflection. 100 m.f.d. cells. All wires and sheath grounded, except one tested.

Outside Wire	#	
1	226	mean throw
2	227·7	
3	220	
4	226·6	
5	225·8	
6	230·3	
7	228·7	
8	228·5	
9	228·3	
10	224·8	
Mean	226·7	

Inside wires # 11 222·8 mean throw
12 210·8
13 215·8
14 210·5
Mean. 215·0

Mean of all wires 223·34
- - leads 13·
- - cable .. 210·34 div., no leakage

Condenser 0·05 f 100 cells

0 – 15	218 div	at rate of	1163 per 100
15 – 30	217		1147
30 – 45	218·5		1157
45 – 60	222·		1181
60 – 75	220		1167
75 – 90	219		1160
90 – 100	74·4		1144·0
	1458·5 div		1158.

$\frac{0.05 \times 210.34}{1458.5}$ = 0·007209 f absolute mean capacity.

= 0·08098 f per mile of 5280'.

Data for the new double-dynamometer for transformer tests.

Larger coil 0·9" wide 0·9" deep. Divided into four windings

1st winding 4 strips of 0·020" thick 0·875" wide one turn on each partition = 2 turns 77,000 sq: mils Total length 1·75'.

2nd - 1 layer of 2 turns in each partition # 16 B.W.G. 0·207" or 4 strips of 0·020" thick 0·2" wide two turns on each partition = 4 turns d.c.c. to 0·255" = 4 turns 41,000 c. mils 32,000 sq: mils.

3rd - 2 layers of # 13 B.W.G. 0·095" d.c.c. 0·108" 7 turns = 14 turns per partition, 28 turns total 9·025 c. mils

4th - 4 layers of # 19 B.W.G. 0·042" d.c.c. 0·054" 15 turns = 60 turns per partition 120 turns total 1,764 c. mils

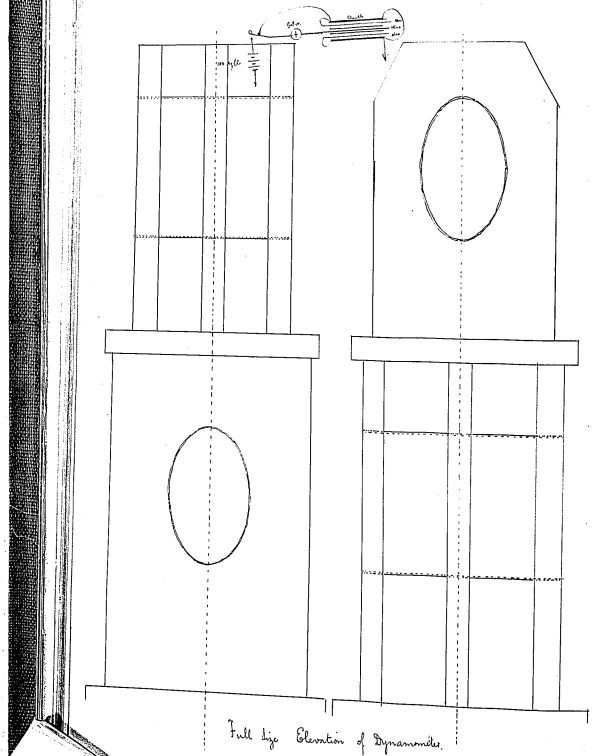
Smaller coil 0·65" wide and 0·7" deep

1st winding 1 layer of 3 turns # 9 B.W.G. 0·148 d.c.c. 0·161" = 6 turns in all

2nd " 2 layers of 7 turns each # 15 B.W.G. 0·072" d.c.c. 0·085". 14 turns per partition, 28 in all

3rd - 4 layers of 15 turns each # 22 B.W.G. 0·028" d.c.c. 0·040". 60 turns per partition, 120 in all

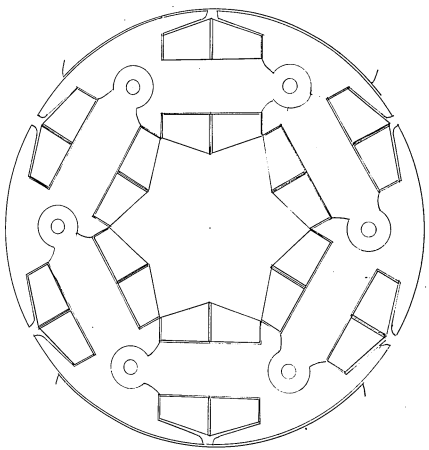
4th - 8 layers of 27 turns # 26 B.W.G. 0·018" d.c.c. 0·021" 216 turns per partition, 432 in all.



Full Size Elevation of Dynamometer.

000567

Armature of hexagonal type to replace pentagon in ⅙ H.P. field, if latter found unsatisfactory.



Determination of the Dimensions and Winding for a new Hexagonal Composite Frame Armature for ⅙ H.P. Field

Voltage of motor = 120

Speed without load	= 1800 r.p.m.	= 30 per sec.
Number of turns needed on arm.	= 3600	all round = 600 per double sp'ol 300 per sp'ol
Winding spaces deminished (inclin.)	= 0.71" × ½(0.55 + 0.32)	= 0.316 sq. ins.
Available winding space	= 0.316 × 0.80	= 0.253 sq. ins.
Space per wire	= 8.42×10^{-4}	sq. ins.
Diam. of wire	= 0.029"	or 0.022" # 24 B.W.G. s.c.c.
Length of one turn	= 5"	= 0.42'
Total length of wire	= 1512'	
" weight " "	= 2.22 lbs.	
" resistance " "	= 32.28 ω @ 20°C	36.92 ω @ 60°C, 41.58 ω @ 100°C
" " between brushes	= 8.07 ω	9.23 ω " 10.4 ω "
Number of commutator bars	= 24.	
Current at full load	= 1.6 amp.	
Drop at full load	= 12 volts. cool, 14.77 volts warm, 16.64 ω hot.	

Voltage of motor 500

Speed without load	= 1800 r.p.m.	= 30 per sec.
Number of turns needed on arm.	= 16,800	
Number on each sp'ol	= 2750	or 1375 on each half sp'ol.
Available winding spaces	= 0.253 sq. ins.	
" " per turn	= 1.80×10^{-4}	sq. ins.
Diameter of wire	= 0.010" # 31 B.W.G.	silk cord. to 0.013"
Length of mean turn	= 5"	= 0.42'
Total length of wire	= 6930'	= 1155' per sp'ol = 577.5' per half.
" weight " "	= 2.10 lbs.	= 0.35 lbs. " " = 0.175 lbs. "
" resistance " " cool 20°C	= 71.5 ω	= 11.92 ω " " = 5.96 ω "
" " between brushes cool	= 17.88 ω	= 2.98 ω " " = 1.49 ω "
" " warm 60°C	= 81.8 ω	= 13.63 ω " " = 6.82 ω "
" " between brushes "	= 20.45 ω	= 3.41 ω " " = 1.70 ω "
Commutator bars	= 48.	

Tests of Copper Bell Motor

Date	Days from Start	Mean torque per amp.	ϕ flux, C.G.S.	Revs. per min. for 100 volts	Frictional Torque	Conditions
		cm. gm.			cm. gm.	
4th Jany 92.	47	1·371	$0·9 \times 10^8$	4·6 (9)	0·463	Same as those tabulated Book V p. 102.
7th . .	50	0·5745				Current supplied to mercury, bell as float only
- -	50	0·99		6,3		Current supplied by nickel electrode in mercury and connected with nickelled cup bell
9th . .	52	1·160		3·7		Nickel electrode in mercury and upper surface of bell nickel plated, disc connected
11th . .	54			3·9		Same
14th . .	57	0·975	0·6 "	3·2		After removing bell, finishing mercury bright, and nothing but mere cleaning done as at beginning
16th . .	59	1·290	1·2 "	4·4	0·23	After washing contacts by amalgam on nickel plate of bell
18th . .	61	1·288	0·9 "	4·2	0·56	After ~~replacing~~ bell and replacing it
23rd . .	66	1·304	1·3 "	4·3	0·20	" " " " " "
25th . .	68	1·293	0·2 "	4·3	0·12	" " " " " "
2nd Feby.	78	1·279	0·5 "	4·3	0·07	1st Feby. Mercury amalgamated with sodium amalgam 2nd upper electrode in cover

Experiments on Foucault currents set up in a large revolving copper arago disk driven by a motor between the poles of a powerful magnet.

A disk of copper 37.8 (14.875") in diameter and 0.815 thick was turned up true in the lathe, and clamped on a motor shaft (10 KWT) firmly with its plane perpendicular to the axis. The current taken by the motor in its armature, with the field separately excited, was about ten amperes and nearly independent of the speed. This represents a steady normal torque of 90 megadyne-cms, or 92.1 kgm. cms. The copper disk was driven at varied speeds between the poles of the large experimental electromagnet. The position of the poles, their separating distance, together with the currents and emfs were observed as follows:-

No. of Obs.	Pole pieces	Distance between poles cms.	Current in magnet coils amps.	Speed of motor r.p.m.	Speed of motor r.p.s.	Current amps.	Current in motor leaving plant amps.	P.d. at motor terms volts	Work in motor watts	Torque at disk. megadyne-cms. kilogram-cms.
	7.4×7.4	1.140	12.5							
1				34	0.5·6 332	16	6	3.24	19.4	5·513
2				46	0.7·6 478	19	9	4.38	39.4	8.24
3				60	1.0·0 625	24	11	5.72	80.1	12.8
4				76	1.2·6 798	29	19	7.25	138.	17.3
5				112	1.8·6 1172	36	26	10.68	278	23.7
6				240	4.0 2510	49	39	23	907	36.1
7				1100	18·3 115	32	22	105	2310	20.1

Repeated same measurements using conical poles instead of flat headed ones. Mean flux density 4000, total flux 14600.

No. of Obs.	Pole piece	Dist. betwn Poles cms.	Current in magnet coil amps.	Speed of motor r.p.m.	Speed of motor r.p.s.	Current in motor leaving plant of mills amps.	Current in motor amps.	P.d. at motor terms volts	Work in motor	Torque at disk kg. polepiece distance
1	Conical	1.2	12.5	12.4	206	12·9	12	7	41·6	81	6.25
2				2×95·6	1·593	20·2	15	10	17.8	178	8.9
3				2×116.4	1·94	24·3	18·5	12·5	21·7	293	12·0
4				2×168.4	2·81	35·3	29·0	16·0	31·3	470	13·3
5				2×305.	5·08	63·8	29·0	16·0	58	870	13·64
6				2×457·5	7·63	95·8	18·5	13·5	85	1150	12·0
7				887	14·8	93·8	18·5	13·5	83	1120	12·0
8				1096	18·25	114·7	18·	12	102	1326	11·6
9				1244	20·73	130·3	18	12	116	1508	11·6

The torque therefore diminishes after a certain maximum has been reached depending on the magnetic field and its space relation to the disk. In this instance the pointed poles produced the greatest torque at 3 cm. from the edge, and the field was much distorted by the currents induced in the copper. A nail resting on the pole piece was elevated its full length when the disk was driven rapidly through the field indicating the dispersion of the resultant field. A B represent in the diagram the position assumed in driving by a nail that normally rests flat on the pole piece.

Synopsis of Data relating to Transformers now built.

17,000 alt. [illegible] min. 141.7 ~ per sec. p. = 890.14

		100 Watt	500 Watt	1 KWatt	2 KWatt	5 KWatt
Dimensions	Length	20·45 8·0"	25·13 9·9"	27·31 10·7"	33·66 13·25	42·6 16·5"
	Over breadth transverse	7·81 2·8"	8·08 3·85"	7·75 3·05"	5·71 3·46"	9·33 3·75"
	Height (Base) upright	6·67 2·63"	9·02 3·55"	9·43 3·91"	10·24 4·43	14·0 6·5"
	" Lid	3·81 1·5"	4·44 1·75"	4·44 1·75	2·08 2·0	6·16 2·46
	" total	10·48 4·13"	13·46 5·30"	9·3" 3·66	12·3 4·85	20·1 8·7"
	Core breadth long	7·11 2·8"	8·0 3·5"	8·0 3·15	8·0 3·5	10·01 3·94"
	Side wall breadth	3·81 1·5"	4·44 1·75"	4·3 1·7"	5·08 2·0"	6·0 2·36"
	Base	3·81 1·5"	4·72 1·86"	4·3 1·7"	4·6 1·81"	6·0 2·36"
	Winding space	0·257" 0·125	1·6 (1·6)	1·6 (5·09)"	(2·16) (3·2)	(10·2)" (3·2)
	Volume of iron	1300 cc.	2180 cc.	2720 cc.	3600 cc.	6980 cc.
	Mass of iron	10·18 kg 22·4 lb	16·85 37 lb	19·14 kg 42 lb	28·03 62 lb	54 kg 119
	Breadth over coils	12·8 5·03"	16·45 6·4"	19·0 7·5"	23·5 9·27"	30·0 11·82"
	Mass of copper	0·8 kg 1·76 lb	2·5 5·5 lb	3·26 kg 7·16	12·25 kg 27 lb	28·1 kg 62 lb
	" " Lamps	0·45 " 1 "	1·24 " 3 "	2·45 " 5 "	2·95 " 6·5 "	3·8 " 8 "
	Total mass.	11·1 " 25·5 lb	20·4 " 45 "	27·24 " 60 lb	42·3 " 93 "	89·9 " 196 "
	Watts per unit mass	Grey 9·0 lb	24·5 11·1 "	36 16 "	47·4 21·5 "	55·2 25·5 "
Winding	Turns of primary/pound	700	700	700	700	400
	" secondary 220 v	168	168	168	168	96
	Primary wire (1000 v)	B.S.S. 20 G. 0·036 C.P. 0·040	B.S.S. 16 G. 0·058 C.P. 0·064	B.S.S. 13 G. 0·092 C.P. 0·101	B.S.S. 11 G. 0·121 C.P. 0·134	B.S.S. 8 G. 0·177 C.P. 0·194
	Secondary wire (220 v)	B.S.S. 26 G. 0·018 C.P. 0·020	B.S.S. 22 G. 0·028 C.P. 0·031	B.S.S. 20 G. 0·036 C.P. 0·040	B.S.S. 18 G. 0·048 C.P. 0·053	B.S.S. 16 G. 0·064 C.P. 0·071
	Space coefficient	1·7	1·4	1·32	1·33	1·4
	Res. of primary	20° C. 120 ohms 25° C. 122·4 ohms	20° C. 40 ohms 25° C. 40·8 ohms	20° C. 20·2 ohms 25° C. 20·6 ohms	20° C. 11·8 ohms 25° C. 12·0 ohms	20° C. 4·1 ohms 25° C. 4·18 ohms
	" secondary	0·216, 0·27, 0·32	0·04, 0·05, 0·06	0·03 0·04, 0·05	0·02 0·03, 0·04	0·01, 0·013, 0·015
Primary	Current no load		0·1	0·1	0·23	0·45
"	" full "		2·63	5·2	2·15	5·5 amps
Secondary	" "	1 amp	2·25	4·5	8·6	21
Drop at secondary terms full load			2·66	3·75	4·0	5·8
" in secondary due to primary			1·46	1·2	1·0	0·67
" " " " " secondary			1·2	1·8	1·2	0·87
" " " " " leakage			0·	1·45	1·5	4·0
Loss of power in primary, no load			76·5	50	130	280
Efficiency at 1/10 load			0·64	0·83	0·78	0·83
" " 1/2 "			0·77	0·90	0·89	0·89
" " 3/4 "			0·77	0·925	0·92	0·91
" " full "			0·82	0·95	0·92	0·92
Ohmic loss of power full load.			12 w	23 w	53 w	69 w.
Surface of iron	100 cm²	1200 cm²	1355 cm²	1992 cm²	2660 cm²	
Cross section of core (min)	20·5	64	62	64	95	
Effective " "	21·7	69·2	57·7	59·5	80·2	
Maximum flux	226,800	226,800	226,800	226,800	339,200	
" density	2,800 / 1,720	3,800 / 3,670	3,988	3,850	4,190 / 3,700	
L/A of mag: ckt:	0·36	0·424	0·583	0·65	0·57	
Surface of iron per watt, full load		15 cm²	2·26 cm²	1·33 cm²	1·33 cm²	
Weight of shell					114 lbs.	
Ratio of Copper mass to total mass	0·0287	0·1226	0·192	0·240	0·316	

Winding of a 2 . KWT Transformer for 10,000 volts.

This is the no 2 (a) 2 KWT transformer that was discarded as a model and whose description is to be found with an outline of dimensions on p. 68. Book V.

Effective Primary voltage = 1000
- Secondary - = 10,000
Primary current at no load = 0·2 amp.
- - - full . = 2·2 .
Secondary - - - = 0·20 .
Primary winding = 450 turns of # 16 B.W.G. 0·065" d.c.c. to 0·078" in two coils of 225 turns each, above and below the secondary.
Secondary - = 4500 turns of # 24 B.W.G. 0·028" d.c.c. to 0·030" in one coil. 60 turns in winding layer, 70·5 layers. Insulation 0·2" round centre, 0·175" above and below and 0·175" on outside. Coil 2·11" wide x 2·975" high.

Length of mean turn = 2·25'
" " primary = 1013 feet
" " secondary = 19120 "
Weight - primary = 13 lbs.
- - secondary = 9·94 -
Resistance - primary = 2·476 - @ 20°C , 2·831 @ 60°C , 3·189 @ 100°C
- - secondary = 3229 ω " " 369·3 ω - - , 416 ω - -
Drop in primary at load = 5·45 volt " " 6·23 volt . . , 7·0 - -
- - secondary . = 64·6 - - - 73·9 - - - , 83·2 - -
Total weight of copper = 23 lbs.

Recalibration of Kohlrausch Dynamometer Wattmeter
Jan 28th.

The dynamometer was recalibrated by resistances and potentiometer as follows

No.	Branch. amp.	T.S. volts 18°C volts	Amps. by Shunt	Amp. by Potent.	Res. in Shunt. ohms	P.D. on Shunt in volts	Watts at Mains	Current in Amp. coil by calculation	Current in Amp. coil by Potent.	Ce.	T
1	2·26	1·217	11·67	12·17	76350	0·8033	122·6	0·9606	0·9613	0·1963	146·
2	2·80	1·519	14·648	15·19	3670	1·5752	122·6	0·03341	0·03163	0·24505	426
3	1·67	0·885	8·577	8·85	37350	1·6377	122·4	0·032644	0·032588	0·2911	219
4	0·188	1·04 0·0750 0·113	0·970	0·975	37320	1·675	121·2	0·033120	0·033323	0·03324	228·6
5	0·588	0·303	3·034	3·030	8005	0·7727	123·3	0·015423	0·015522	0·014708	335·
6	0·245	0·1267	1·264	1·247	7855	0·7801	123·1	0·01567	0·01567	0·019734	137·
7	0·096	0·1254	0·1244	0·1252	7635	0·8103	123·3	0·016015	0·01647	0·007386	317·5
8	0·033	0·179	0·170	0·179	7595	0·8180	122·8	0·016147	0·016143	0·003941	433·0
9	0·032	0·1782	0·1691	0·1782	3770	1·6335	122·3	0·032446	0·032280	0·003646	353·6
10	0·080	0·4121	0·4128	0·4121	18420	0·6332	123	0·006606	0·006791	0·002799	323·5
11	0·035	0·1761	0·1806	0·1761	18,270	0·3295	123·3	0·006749	0·006817	0·001200	1140·5
12	0·015	0·0761	0·0774	0·0761	8,395	0·7343	123·3	0·011469	0·011475	0·001122	1327
13	0·035	0·1767	0·1806	0·1767	8,185	0·7826	122·0	0·01534	0·01542	0·002726	3155·

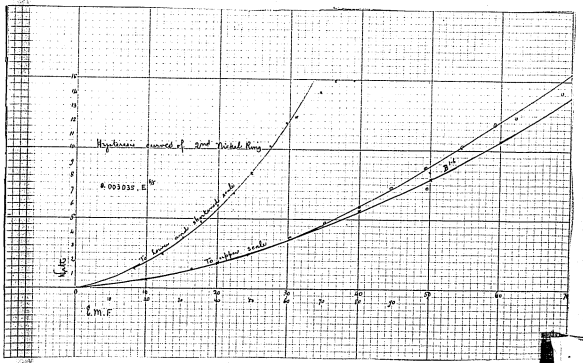
		28 Dec: 91.	28 Jan 92	d
# 1	1·334 x10⁻³	1·337 x10⁻³	1·335 x10⁻³	
			1·128 . .	
			1·329	
# 2	1·421 x10⁻³	1·407 x10⁻³	1·441 x10⁻³	
			1·407 .	
			1·427	
# 3	2·375 x10⁻⁵	2·317 x10⁻⁵ 2·194	2·326 x10⁻⁵	
			2·391 x10⁻⁵	
			2·235 x10⁻⁵	
# 4	8·514 x10⁻⁴	8·570 x10⁻⁴	8·652 x10⁻⁴	
			8·514 -	
			8·1258 -	
			8·631 -	

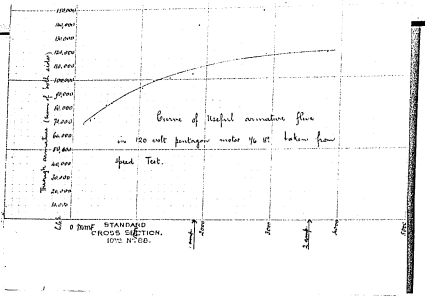
Test of Second Nickel-Wire Ring for Hysteresis.

Jan. 23 1906

The following wattmeter readings were taken with the nickel wire ring mentioned on page 20. Rad. 20. mean 1.92 cent.

Test No.	R	α	T	Deflection Pot. (Watts) on cent		γ"	RT	Power in coil:	Power Lost in Sup. coil:	Power Lost in ring	Net power
					H steadily increased						
1	1057	2.360×10^{-5}	124°	24·5	0		1.31×10^5	3·098	0·57		2·43
2	1170		57	16·5	0		6.668×10^4	1·577	0·24		1·34
3	2378		71·5	30·25	0·1	0·01	1.701×10^5	4·022	0·39	0·02	3·61
4	2331		95·5	35·25	0·1	0·01	2·227 -	5·267	0·53	0·02	4·72
5	2338		120·5	03 40·25 40	0·15	0·0222	2·818 -	6·664	0·69	0·050	5·92
6	2368		146·5	00 45° 44	0·2	0·014	3·469 -	8·202	0·86	0·08	7·26
7	2668		155·5	46 50 44	0·3	0·09	4·1148 -	9·910	0·944	0·18	8·69
8	2908		167	03 55·2 52	0·34	0·1156	4·857 -	11·449	1·05	0·23	10·21
9	3278		171	01 60·24 594	0·42	0·1764	5·605 -	13·246	1·11	0·35	11·8
10	3178		188	00 63·2 642	0·5	0·25	5·976 -	14·13	1·26	0·5	12·37
11	3708		188	05 70·2 687	0·74	0·5476	6·970 -	16·49	1·33	1·1	14·06
12	3958		193·5	09 74·8 709	0·93	0·865	7·660 -	18·121	1·341	1·73	14·98
13	3628		202	14 80·5 719	1·3	1·69	8·780 -	20·77	1·79	3·38	15·6
14	3838		258	24 89·5 814	1·70	2·96	9·982 -	23·162	1·92	5·92	15·58
15	3268		335	43 90·5 814	2·15?	4·62	10·95 -	25·90	2·51	9·244	14·15




Curve of useful armature flux
in 120 volt pentagon motor ¼ H.P. taken from
Speed Test.
Through armature (lines of force units)
0 MMF STANDARD
CROSS SECTION.
10TH NOTCH.

Test of 1/6 H.P. motors on first completion 26th January 92. (30)

Weight of motors without fans 24¼ lbs.

Resistance of 500 volt armature 135 ω, Resistance of 120-volt. armature 60 ω
" " " field 279 - " - - - field 10 ω
" - - - field + arm: 414 ω " - - - field + arm: 150 ω.

Armature windings as per specification see Book V. p 133

Field windings 500 volt fields each spool 29 ⅓ layers of 120 turns + 50 turns in last layer. Total number of turns on both spool 7,060

120 volt: field each spool 13 layers 53 turns. Total number of turns on both spool 1378

Diameter of 120 field over binding cord 7.15 = 2.8"
- - 500 - - - 6.75 = 2.65"

Magnetic Test of 120-volt motor.

Test No	Current in field Amp	MMF in circuit	Current in armature	P.D. at armature	Drop in armature	E.M.F. of armature	Speed R.p.m	R.p.s	Reduction coil & fork per R.p.s	Useful flux	f
1	0·216	1878	0·62	50	3·6	46·4	637	10·62	4·37	136,500	1·376 x10⁻⁵
2	0·315	2815	"	50	"	"	588	9·8	4·734	148,000	1·402 "
3	0·517	4622	0·7	49·5	"	45·9	541	9·02	5·087	159,000	2·907 "
4	0·529	4·278	7410	"	49·5	"	527	8·78	5·227	163,400	4·535 "
5	0·409	2·110	3655	"	48·5	"	544·9	9·03	4·97	155,300	2·354 "
6	0·335	1·532	3174	"	49·5	"	45·9	566	9·43	4·866	152,100	2·087 "
7	0·360	1·858	3218	"	48·5	"	44·9	715	11·92	3·767	117,700	2·732 "
8	0·411	2·121	3674	"	47	"	43·4	695	11·58	3·748	117,100	3·138 "
9	0·322	1·662	2879	"	47	"	"	695	11·58	3·748	117,100	2·459 "
10	0·425	2·193	3799	"	47	"	-	683	11·38	3·748	117,100	3·245 "
11	0·272	1·404	2432	"	46·7	"	43·1	768	11·8	3.653	114,200	3·327 "
12	0·200	1·032	1787	"	46	"	42·4	761	12·68	3·345	104,500	1·710 "
13	0·161	0·831	1440	0·7	46·5	4·2	42·8	782	13·03	3·246	101,400	1·420 "
14	0·134	0·691	1197	"	48	"	42·8	827	13·78	3.178	99,300	1·286 "
15	0·115	0·593	1027	"	47·2	"	43·0	854	14·23	3.021	94,400	1·088 "
16	0·086	0·444	769	"	47·5	"	43·3	903	15·05	2·877	89,900	0·855 "
17	0·064	0·332	575	"	47·5	"	43·3	980	16·33	2·651	82,830	0·694 "
18	0·055	0·284	492	0·75	48	4·5	43·5	992	16·53	2·632	82,240	0·598 "
19	0·034	0·175	303	0·8	48	4·8	43·2	1119	18·65	2·316	72,370	0·419 "
20	0·028	0·144	249	0·850	48	4·9	43·1	1150	19·16	2·249	70,280	0·354 "
21	0·021	0·108	187	0·879	47·5	4·9	42·6	1180	19·16	2·224	69,500	0·269 "

The airgap is 0.075 , 0.028" and the length of pole face 12.5
the breadth of the armature 2.1 , the pole area 26.25 sq cms.
Calculated reluctance $\frac{0.15}{26.25}$ = 5.7 m.m.

Synopsis of Data for the Edison slow speed Motors.

	150 v.				500 v.				
	½ H.P. ½ K.W. 10 volts				1 K.W.T.	½ H.P.			1 K.W.T.
Ext: diam: of armature	5·675"	6·125"			7·5"	5·675"	6·125"		7·5"
Number of segments	4					4	6		
Core breadth	0·625"	0·75"			1·75"	0·625"	0·75"		1·75"
Core depth	0·625"	0·75"			1"	0·625"	0·75"		1"
Cross section	2·5	3·0	3·5		1·75"	2·5	3·0		1·75"
" effective	2·13					2·13			
Weight of iron in core	2lb 11oz.					2lb. 11oz.			
Polar bore	5·75"				7·53"	5·75"			7·53"
Centre	5·05"				4·15"	5·05"			6·015"
Length of polar face									
Polar effective surface									
Number of spools	4					4	6		
Number of commutator bars	16	24			36	32	48		72
Number of turns on arm:	6000	8,000			1332	21,600	16,000		444·52
Turns per commutator bar	375	333			37	675	333		62
Gauge of wire on arm:	# 27 B.W.G.	# 26 B.W.G.			# 18 B.W.G.	# 23 B.W.G.	# 24 B.W.G.		# 20 B.W.G.
Diameter of bare + cord. wire	0·02" 0·025"				0·049" 0·051"	0·029" 0·031"	0·027" 0·029"		0·045" 0·051"
Resistance of armature	24 and 28 Ω				1·01 Ω hot	3·0 Ω hot			23 Ω hot
Full load current	1 amp.				8·5	0·32 amp.	0·4		2)
Drop in armature	2·5 volts				8·5 v.	7·5 v.			46·0
Energy in armature at full load	25 watts				72 w.	18·6 w.			92
Weight of wire on arm:	11lb. 12 oz.					1·0 lb			
Length " "	2080'								
Weight of armature									
Diameter of field cores	1·9" 3·6				2·9"	1·9" 3·6			2·8"
Cross section " " "	10	3·25	4·5	5		10	2·25	4·5	
Winding diameter	1·45"					1·45"			
External "	2·1"				4·7"				4·7"
Weight of field wire	10. 12 oz.					1·25 lb.			
Diameter of field wire (bare)	0·015" 0·025"					0·015" 0·025"			
Number of turns	2,304								
Length " " "									
Resistance " " "	39 Ω and 44 Ω					1·20 Ω and 1·35 Ω hot			
Armature flux	87,000				4,00,000 lines 350,000 lines	87,000			4,00,000 lines 350,000 lines
" density	17,000					17,000			
Leakage factor for full load	1·9				1·6 per cent	1·9			1·6 per cent
Speed light	1650				1500	2000			1600
Speed at full load	1000				1250	1290			1400
Hysteresis in armature						11			
Current at full load	1 amp.				8·5	1·25			2
Commercial eff: " "	0·4					0·42			
Electrical loss of power " "	66					46			
Mechanical friction " "	25 watts					25			
MMF. " " "	2250								
Reluctance " "									
Interflange of field spools	1·7"				6·6"	1·7"			6·6"
Current in field at no load	1 amp.				8·5	1·25			2
" " " full "	1 amp.				8·5	0·25			2
Energy " " "	90 watts.					26 watts.			
Weight of machine	20 lbs.	25 lbs.			113 lbs.		214 lbs.		113 lbs.

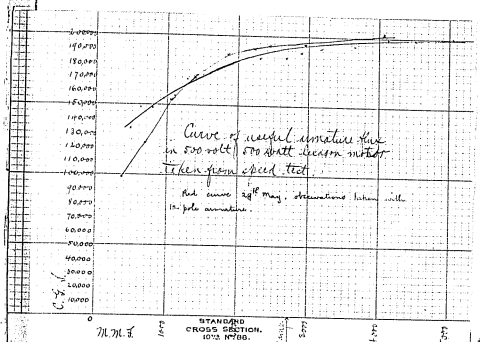
Corresponding Data for 120 volt Machine

Power	= 220 volts 500 watts	
Emf at terminals	= 120 volts	
Current at full load	= 4·2 / 0·7 = 6	
Speed running light	= 1700 r.p.m. = 28·3 r.p.s.	
Armature Plate	= 200.000	
Number of wires all round	= 2 × 6 = 2112	
Number of commutator bars	= 24	
Number of segments	= 6	
" of spools	= 12	
Number of turns per spool	= 177 say 176	
" " coils per bar	= 88	
Winding space per spool	= 0·3658 sq. in.	
Effective " "	= 0·311 " "	
" " per turn	= 17·67 × 10⁻⁴ "	
Diameter of covered wire	= 0·042"	
" " bare wire	= 0·035" # 20 B.W.G. S.C.C.	
Mean length of one turn	= 0·84'	
Total length on armature	= 1121 '	
" weight " "	= 4·23 lbs.	
resistance of winding, total	= 2·14 ω @ 20°C. , 2·75 ω @ 60°C , 3.1 ω @ 100°C.	
Pressure lost in arms at load	= 12·4 volts . . 16·5 volts . . 18·6 volts . . .	
" " activity lost in arm . .	= 56·4 watts . . 99 watts . . 111.6 watts . .	
Volumes of iron in armature core	= 24 × 9·5 c.i.	
" hysteresis	= $\eta B_{max}^{1.6}$ vol. $\left[2\pi \times (17{,}000)^{1.6} \times 0.00333 \times 28.3\right] = 0.0597 \times 9\mu \times 10^{-16} \times 2410$	
Field winding Series	= 3·8 lbs of # 17 B.W.G. 0.055" s.c.c. & 0·064"	
Resistance of field	= 1·05 ω @ 20°C 1·204 ω @ 60°C. 1·36 ω @ 100°C.	
Drop in field at load	= 6·3 v. . . 7·2 v . . 8·2 v . .	
Energy " " "	= 38 w . . 44·240 w . . 49 w . .	
Interflange	= 5·0"	
Turns per layer	= 68	
Layers	= 5·2	
Depth of winding	= 0·33"	
Length of wire	= 340'	
Mean length of one turn	= 0·73	
Total number of turns	= 570	

Armature M.M.F. across air gap (max) = $\frac{2112}{\pi} \times \frac{6}{2} \times \frac{1}{68}$ = 2000 amp.

Pole M.M.F. " " = 0·075 × 5,500 = 412·5

σ = 0·2 appx.

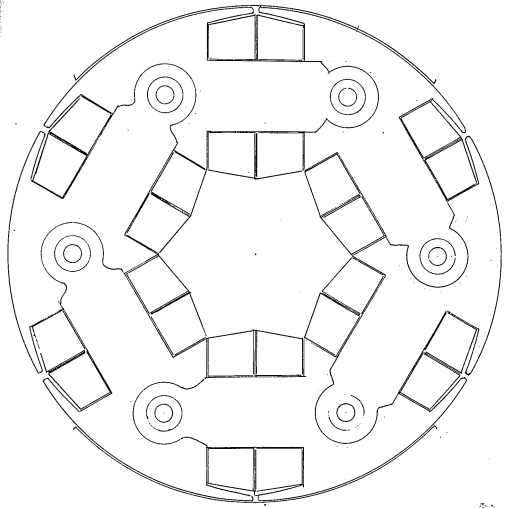


Curve of useful armature flux in 500 volt 500 watt Lucas motor taken from speed test.

Red curve 28" mag. characteristic taken with 12 pole armature.

500 - Watt Motor

Full - sized section of Armature through plane of plates.



Dimensions and Design for a 500-Watt Motor

Power = 500 Watts

E.M.F. at terminals = 500 volts Current @ 0.79 = 1.267

Speed running light (shunt) = 1700 r.p.m. = 28.3 r.p.s.

Armature Flux = 200,000

Number of wires all round = 8818 say 8640

Number of segments = 6

Number of Spools = 12

Number of commutator bars = 48

Number of turns per spool = 735 say 720

" " " per centre bar = 180.

External diameter of arm. = 7.0" (17.78)

Radius of coil centres 1 = 2.35"

Radius of his. bolt centres = 2.6"

Winding space section on spool = 0.63" × 0.58" = 0.3655 sq. in.

Effective " allowed = 0.85 × 0.3655 = 0.318 sq. in.

Space per turns = 0.311 ÷ 720 = 4.314 × 10⁻⁴ sq. in.

Cond. Diameter of turns = 0.0208"

" " wire = 0.018" # 26 B.W.G. D.S.C.C. 0.021"

Mean length of one turn = 6.5" = 0.54'

Total length on armature = 4667'

" weight of wire = 4.6 lbs. (Actual Weight as constructed 4 lbs.)

" resistance between brushes = 37.22 @ 20°C. 42.57 @ 60°C. 47.95 @ 100°C.
14.72 actual

Estimated drop in arm. = 53.22 volts . . 60.87 volts . . 68.5 volts . .

" Energy lost in arm = 76.1 watts . . 87.0 watts . . 98.0 watts . .

Surface of iron without teeth = 22.7 sq. ins. = 136.2 sq. cms. on armature.

Thickness of iron = 2.5 cms. 0.98"

Mass of iron in armature = 58.6 lbs. 26.66 Kgms.

Cross section of armature = 6.25 sq. cms. say 6. effective.

Flux density in " = 16,670

Estimated hysteresis = 18 watts

Polar angle = 93°

Length of polar arc = 14.3

Entrefer or clearance = 1/32" 0.08

Air gap reluctance (total) = 2 × 0.08 ÷ 36 = 0.16/36 = 4.4 m.le.

Pole surface = 36.0 sq. cms.

Armature reluctance = 12 cm /5.1 × 3.5 ×10⁻³ = 7 ×10⁻³

Field " = 40 cm /10 × 2 ×10⁻³ = 8 ×10⁻³

Total estimated reluctance = 19.4 m.le. say 20

Exciting power needed = 388 4,000 for full flux

Amp. turns " = 3,200 " "

Leakage coefficient = 2.0

Flux allowed through field = 400,000 at full load.

Flux density = 16,670

Cross section " = 24 sq. cms. = 5.53 sq. ins. dia.

Diameter of field core = 2.45" say 2.250" = 5.72 cm = 2870 sq. cm = 16,600

Interpolings = 5.0"

Mean diam. of winding = 2.75" inc. = 8.64" = 0.72'

Total number of turns = 3200 × 2/3 = 6400/3 = 2130.

" length = 1534'

Resistance allowed = 1944 @ 60°C. = 10.87 ×10⁻³ ω per foot

Series winding. Diameter of wire of field = 0.028" s.c.c. 0.029" # 22 B.W.G.

Resistance " " " = 20.8Ω @ 20°C. 23.1 ω @ 60°C 26.9 ω @ 100°C.

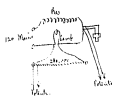
Drop in " at full load = 25.9 volts . . 33.0 volts . . 37.2 volts . .

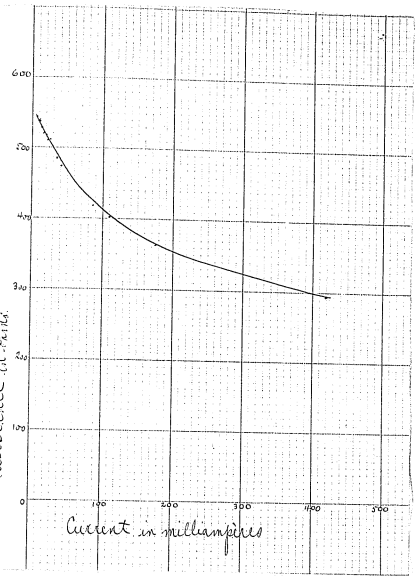
Energy " " " = 44.9 watts . . 49.2 watts . . 48.9 watts . .

Weight of wire . . . = 3.65 lbs.

Turns in one layer = 140

Layers = 15 Depth of winding 0.58"




600
500
400
300
200
100
0
100
200
300
400
500
Current in milliampères

Measurement of the resistance of a 16 c.p. lamp at different current strengths passing through it. Feby. 3rd

An ordinary 16 cp. lamp marked for 119 volts. Bamboo filament, was tested for resistance by inserting a larger adjustable resistance between it and the 120 volt mains, while measuring pressures with a voltmeter.

No. of Obs	Current in milliamperes	Potential on 10,000	Volts on lamp	Res. of lamp	Potr reading on resr.	
1	6·70	10,000	3·639	543 ω	0·18733	
2	10·2	"	5·454	537	0·2577	
3	13·5	"	7·121	528	0·3391	
4	17·3	"	9·015	520	0·4293	
5	20·3	"	10·525	518	0·5012	
6	22·1	"	11·264	510	0·53614	
7	26·7	"	13·610	511	0·64821	
8	35·5	"	17·182	484	0·8182	
9	41·5	"	19·646	473	0·9355	
10	86·4	"	36·21	419	1·7243	
11	109·9	5000 ω	44,100	401	1·0500	
12	174·6	"	63.302	363	1·5072	
13	419	3000 ω	122·395	292	1·7485	

Particulars observed at the McElraine Execution by Electricity

11. 10. 00

Mr. Elraine entered room

1st Contact between jars holding brine with hand commenced (current passing from hand to hand) 11. 11. 49 } 50 secs.
" 12. 39 }

1600 volt 2·0 amp 2·1 27 30 finally 3·1 5·6 ω

Interval of 43 secs. for examination — Slight reflex action.

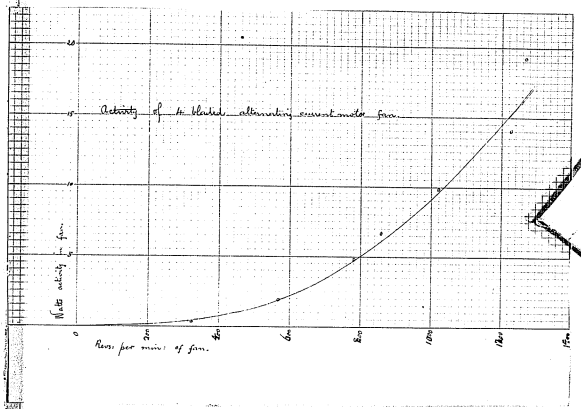
2nd contact between head electrode on forehead and another electrode on calf of right leg 11. 13. 22 } 36 secs.
11. 13. 58 }

2·11 ω

1500 volts 7 amp. steadily.

No reflex action visible in any part of the body except the cremaster muscle in the examination made at 11.14.00

Energy in watts/sec for	E^2R.	Rev. of motor	C^2	Power in form watts
17.5	28.3	2.4 r.p.m.	10.89	2.0
12.4	37.4		14.59	2.75
13.7	24.5	2.6 r.p.m.	11.36	1.75
12.2	22.8		8.76	1.0
24.4	47.4		19.23	6.0
32.7	58.3		21.25	7.3



Test of small Excelsior Alternating Fan Motor. Jan 26th.

The fan motor was coupled up with an ammeter, a voltmeter, and a dynamometer watt meter so as to measure the currents and energy absorbed.

Speed in Revs per min	Amperes in Motor circuit	Volts	Resistance in Motor circuit	Torsion	α	$R\tau$	Energy in Motor watts	Speed of motor	Power in Dynamo circuit watts	Net power in motor watts
77°	3.30	46	6.210	54.5	1.42×10^{-6}	338,400	48.05	5.80	0.34	47.71
103°	3.82	44.3	"	60.5	-	376,700	53.25	6.51	0.32	52.93
86°	3.37	39.5	6.100	51	-	311,100	44.17	5.49	0.26	43.91
62°	2.96	38.3	2.140	127	-	271,800	38.59	4.54	0.58	38.01
129°	4.27	50.75	2.180	255	-	558,900	78.96	8.55	1.18	77.76
150°	4.61	55	4.160	162.5	-	676,000	95.99	9.26	0.73	95.26

Power absorbed in driving the fan at speed.

Motor in floating dynamometer and driving fan on same coincident shafts.

Speed of fan	Revs per min of fan	Balance lb	Moment	$6.165 \times$ Moment	Activity watts	E.M.F. at fan motor terminals	Current in fan motor	Activity in motor
324	5.14	50 gms @ 2.2	110	6.782×10^5	9.366	79	2.22	17.38
568	9.47	6.4	320	1.973×10^6	1.958	10.5	2.87	30.1
858	14.3	14.2	710	4.377	6.609	14.5	3.73	54.1
1020	17.0	18.5	925	5.703	9.695	17.0	4.18	71.1
1272	21.2	28.2	1410	8.692	18.43	22.	4.90	107.8
1224	20.4	22.2	1110	6.843	13.96	20.8	4.85	100.9
1020	17.0	18.7	935	5.764	9.80	18.8	4.52	85.0
780	13.0	11.7	585	3.607	4.689	15.5	3.93	60.9

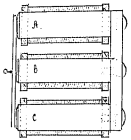
Int Diam of field magnet circle = 12.15 area 116 sq cms.

Length " " cylinder = 6.1

Volume = 707.6 c.c.

Deducting $6.1 \times 1.5 \times 4.35$ = 39.8

667.8 c.c.



Reluctance of ϵ circuit $\frac{0.636}{0.01} + \left(\frac{0.636}{0.08} \times \frac{0.636}{0.196}\right) \Big/ \left(\frac{0.636}{0.01} + \frac{0.636}{0.006}\right)$

$63.7 + \left(\frac{15.72 \times 9.43}{15.72 + 9.43}\right)$

$15.72 + \frac{148.3}{25.15}$

$18.92 + 5.90$

21.62×10^{-3}

Where the current in the short was 1.12 } representing a short mmf of 716
The pull was 185 gms with C }
224 " " D } showing effect of unequal air gaps.
293 " " A }

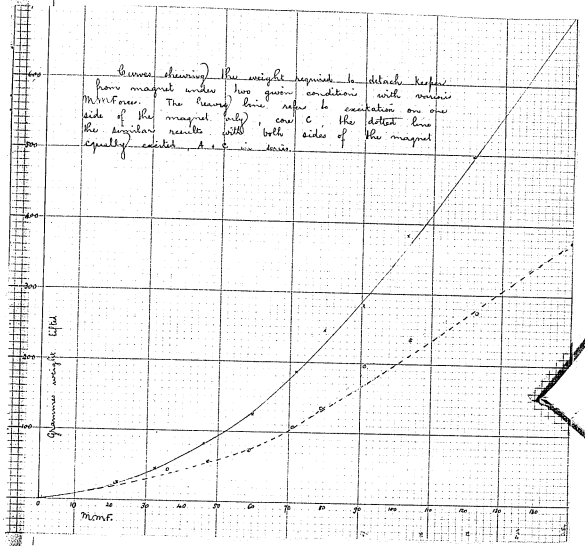
With same current and pair of coils in series and the poles in armature
The pull was 510 gms with A + C
510 " " B + C
420 " " A + C

$\frac{0.240}{0.636} = 15.72 \times 10^{-3}$

$\frac{0.148}{0.636} = \frac{9.43}{25.15}$

12.59

37.74



Curves showing the weight required to detach keeper from magnet under two given conditions with various M.M.F.ces. The heavy line refer to excitation on one side of the magnet only, coil C, the dotted line the similar results with both sides of the magnet equally excited. A + C in series.

Measurement of Tractive force of a small Electromagnetic Relay. 16th Feby. 92

A triple coil magnet of the dimensions shown in section on the opposite page was mounted like a relay with an armature of soft iron horizontally pivoted before its poles. There were 50 turns of 26 BWG 0·033" silk covered to 0·038" in two layers of 25 turns on each coil making 150 turns on the whole apparatus. The resistance of each coil was 0·058 Ω at 15°C and its inductance with the armature also in the attracted position was 0·075 & 2·3 f = 0·1403 Ω. The adjusting screw was set that the clearance at the pole A was 0·01 & at C 0·01 with the armature attracted. The diameters of the pole faces were each about 0·9 making an area of 0·636 sq". The relay was worked with the armature horizontal. By means of a bracket the pull at the centre of the armature necessary to dislodge the latter against attractive force was observed under various conditions of exciting power.

1st Current through C only. other coils out of circuit.

Weight of pan	Weights on pan	Total weight lifted	Pull Dynes	Ohms	Amp	MMF	Calculated Flux	B calculated from flux	B calculated from pull
23·81	1·38	25·2	2470	0·068	0·35	22·0	1018	801·6	1276
	22·2	46·0	4510	0·100	0·516	33·43	1500	1181	1720
	57·0	80·8	7930	0·142	0·733	46·07	2131	1678	2285
	100·5	124·3	12,200	0·184	0·950	59·70	2762	2175	2820
	161	184·8	18,130	0·221	1·140	71·64	3315	2611	34.50
	221	244·8	25,000	0·245	1·265	79·50	3678	2897	4050
	259	282·8	27,750	0·278	1·435	90·20	4173	3287	4272
	355	381·8	37,460	0·318	1·642	103·2	4774	3760	4961
	475	498·8	48,940	0·375	1·936	121·7	5620	4434	5675
	680	703·8	69,040	0·462	2·384	149·8	6930	5457	6740

2nd Series. Current through coils A + C in series like poles to armature.

Weight of pan	Weights on pan	Total weight lifted	Pull Dynes	Ohms	amp	MMF in each coil	Calculated in Flux each coil	B calculated in A from armat	B calculated from pull
23·81	0·50	23·8	2336	0·067	0·346	21·75	1576	905	-
	20·5	44·3	4,347	0·111	0·573	36·0	954	1500	-
	32	55·8	5,476	0·145	0·748	47·0	1245	1957	-
	44	67·8	7,144	0·181	0·934	58·7	1555	2445	-
	54	107·8	10,580	0·219	1·130	71·0	1881	2957	-
	110	133·8	13,130	0·244	1·259	79·1	2096	3295	-
	172	195·8	19,210	0·281	1·450	91·1	2411	3795	-
	210	233·8	22,940	0·321	1·657	104·2	2761	4341	-
	250	273·8	26,870	0·379	1·956	122·9	3256	5118	-
	350	373·8	36,680	0·462	2·385	149·9	3972	6244	-

Edison = Lalande Batteries for operating the G.N.W. telegraph lines in Toronto Station

	Number	Name		Length	Total res.	Res. added	
	No 1	G.T.R.	East	333	19,000	–	1
	4	"	"	161	9500	500	2
	8	"	"	276	12,000	–	3
	11	"	"	360	11,100	–	4
	12		"	360	10,000	–	5
	14		"	272	9,350	650	6
	1	G T R	West	169	15,000	–	7
	3	"	"	120	9,100	900	8
	12	"	"	189	8,400	1600	9
220 cells	16	"	"	142	7575	2425	10
EMF 154 volts	35		"	200	8000	2000	11
Int. res. 11 ω	1		North	124	8270	1730	12
Current 18 x 0.03 = 0.54	3		"	237	12,800	–	13
Life time 600 hrs.	4		"	227	8000	2000	14
	5		"	171	8350	1650	15
	9		"	125	8000	2000	16
	14		"	193	9200	800	17
	1	CVR	"	125	8700	1300	18
	2	G T R.	East	340	5850	1150	19
	$ 9		"	333	7000	–	20
	13		"	163	4590	2410	21
	15		"	333	6500	500	22
	23		"	333	6500	500	23
	2		West	175	6500	500	24
	$ 2	"	"	229	4700	2300	25
	6		"	196	6900	100	26
150 cells	9		"	100	6900	100	27
EMF 105 volts	14		"	100	5000	2000	28
Int. res 7.5 ω	30		"	117	5130	1870	29
Current 19 x 0.03 = 0.57	34		"	142	6770	230	30
Life time 600 hrs.	39		"	257	7000	–	31
	15		North	75	4900	2100	32
	16		"	153	6470	530	33
	17		"	161	5740	1260	34
	21		"	227	7000	–	35
	2	CVR	"	87	6300	700	36
	Toronto	Bell	"	100	6100	900	37
	10		West	120	3100	200	38
	15		"	120	3300	–	39
	31		"	120	3200	100	40
	33		"	40	1200	2100	41
	37		"	120	2800	500	42
	49		"	120	2330	970	43
	50		"	120	2300	1000	44
75 cells	1	City		10	1100	2200 ?	45
EMF 52.5 volts	2	"		15	2310	1090 ?	46
Int. res. 3.8 ω	4	"		15	2930	370 ?	47
Current	5	"		2	750	2580 ?	48
Life	Gold Stock			2	700	2630 ?	49

Calibration of Alternating Current Ammeter for Aubrey

16th Feby. 92

This is a standard 12-ampère continuous current meter arranged for electrostatic purposes by inserting a coil of many turns in a sector box on the extremity of an aluminium arm. The instrument was inserted in circuit with the Siemens dynamometer, and calibrated from 0 up to 9·5 ampères. The readings of the pointer extremity is 14·2 ± 5 cms. and the chordal distances along this circle from the zero point are:- 0·5 – 0·175 , 1 – 0·37 , 2 – 0·9 , 3 – 1·9 , 4 – 3·05 , 5 – 4·55 , 6 – 6·25 , 7 – 8 , 8 – 9·75 , 9 – 11·9 ,

The resistance of the instrument is 0·023 ω at 18°C.
" inductance " " " 0·069 mh. at no load 0·104 mh. at full load

On the density of the luminiferous ether, by Thomson's method.

The energy in heat in the vicinity of the earth due to solar radiation is about 50 micrergs per c.c., (on Thomson's data derived from Pouillet 3q), If m be the ether mass per c.c. or density of ether. Then mv^2 is a superior limit of the energy per c.c. Assume $v = \frac{V}{n}$ where V is the velocity of transmission = 3×10^{10} Then $\frac{mV^2}{n^2} = 50 \times 10^{-6}$ is our fundamental equation or

$$m = 50 \frac{n^2}{V^2} 10^{-6}$$

$$= \frac{50}{9 \times 10^{20}} n^2 . 10^{-6}$$

$$= 5·5 \times 10^{-28} \times n^2$$

Thompson assumes that n cannot be less than 50 whence

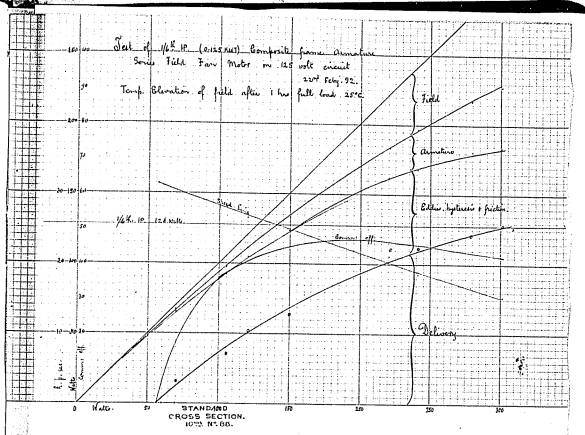
$$m = 1·38 \times 10^{-26} \times 10^{+2}$$

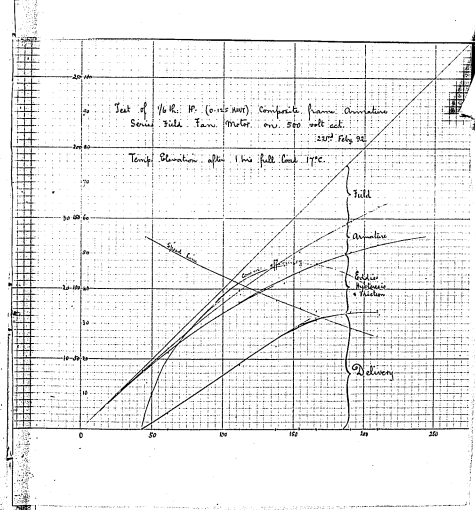
$$= 1·38 \times 10^{-24}$$

No. of Test	Time	Volts at motor terms.	Watts	Amperes thro' motor	Drop in field	Res. of field	Energy in motor	Energy in field	Energy in armt.	Res. of armt.
1	13·20	125	0·187	0·552	5·5	10·0	69.	3·0	66.	6·5
2	·20	125	0·110	0·568	5·8	·2	71	3·3	67·7	6·5
3	·30	125	0·163	0·836	8·7	·4	104·5	7·3	97·2	6·6
4	·35	124	0·189	0·975	10·3	·6	121	10·0	111·0	6·6
5	·42	124	0·236	1·218	13·2	·8	149·5	16·1	133·7	6·7
6	·49	124	0·355	1·832	20·2	11·0	221·7	37·0	184·7	6·7
7	·55	120·5	0·389	2·007	22·5	·2	241·9	45·1	196·8	6·8
8	14·06	120·2	0·450	2·322	26·5	·4	279.	61·5	217·5	6·9
9	·15	119.	0·491	2·534	29·4	·6	301·6	74·5	227·1	6·9
10	15·05	121	0·496	2·560	30·2	11·8	310.	77·3	232·7	7·1
1	16·00	497	0·017	0·0877	24·3	277	43·6	2·1	41·5	144
2	·10	497	0·0244	0·1238	34·5	279	61·5	4·3	57·2	150
3	·20	497	0·0444	0·227	69·8	281	112·4	14·5	97·9	151
4	·25	498	0·0514	0·2786	78·8	283	138·0	22·0	116·0	152
5	·30	498	0·060	0·3097	88·3	285	155·5	27·4	126·1	153
6	·32	497	0·065	0·3384	96·3	287	166·7	32·3	134·4	154
7	·36	500	0·074	0·3819	110·4	289	190·9	42·2	148·7	155
8	·45	497	0·082	0·4232	122·7	290	210·4	51·9	158·5	156
9	17·00	497	0·082	0·4232	120·4	308	210·4	55·8	158·2	161

Res. of 120 volt motor after test:- Field 11·8, Armt. 7·1 } Total 19·9 Temp on field 112°F, Air 68°F } Rise 44·5°F

120-volt motor driving c.c. large 6 bladed fan makes 1420 rpm. taking 0·55 amps.




Test of 1/6 H.P. (0·125 KW.) Composite frame Armature
Series Field Fan Motor on 500 volt circ.
23rd Feby. 92.
Temp. Elevation after 1 hrs full Load 17°C.
Field
Armature
Eddies Hysteresis & Friction
Delivery

Tests of 1/6 H.P. Motors with wrought armatures 120 and 500 volts as finally prepared before delivering 22nd Feby 92

Weight of 120. volt machine on wooden bases 26 lbs.
External dimensions 20cm x 9cm (nearly) occupied.
Res. of field @ 18°C 9.92 ohms. Armature 6.5 ω Total 16.42 ω.
Number of turns on armature 3592. all round 1.322" 1.132".
" " field 1378 0.028" 0.040".
Weight of 500 volt machine on wooden bases 25½ lbs. Same ext. dimensions.
Res. of field @ 18°C. 2770, Armature 1149. ohms Total 4.26.4 ω.
The two motors were coupled by a double Hooke joint & rod, the 120 volt motor being mounted in the floating cradle, and the 500. volt motor outside.

Load in lbs.		Speed		E.M.F. of armt.	Brake hors. power	Effcy.	Volts	Amps.	Watts	Efficiency	Remarks
Inside	Outside	r.p.m.	r.p.s.								
1.5	1.5	1878	31.3	116.	3.705	64.2	52 @ 1.30	–	–	64.2	–
3.7	2.1	1950	32.5	115.5	3.55	65.6	52 @ 1.6	800	16.0	49.6	0.225
5	4.6	1686	28.1	110.8	3.94	92.6	52 @ 1.41	2050	35.5	57.1	0.349
4	6.2	1593	26.6	107.3	4.03	104.8	52 @ 2.3 / 120 @ 1.1	3150	51.7	53.1	0.427
12	10.0	1489	24.8	101.6	4.10	123.7	52 @ 2.3 / 120 @ 1.5	4165	63.7	60.0	0.425
13	12.5	1365	21.1	98.5	4.20	162.2	52 @ 2.5 / 120 @ 1.7	5175	110.3	52.	0.498
17	27.4	1183	18.6	84.3	4.83	168.4	52 @ 3 / 120 @ 2.5 / 120 @ 1.8	9600	110.7	57.7	0.458
18	36.7	1008	16.8	77.9	4.64	180.8	52 @ 4 / 120 @ 3 / 120 @ 2.2 / 120 @ 1.6	11.700	121.2	79.5	0.434
15	44.3	909	15.2	72.1	4.74	182.8	52 @ 4.2 / 120 @ 3 / 120 @ 2.5 / 120 @ 1.8	13.650	127.9	93.7	0.422
12	46.6	909	15.2	72.6	4.78	186.8	52 @ 4 / 120 @ 3 / 120 @ 2.5 / 120 @ 1.8	14.050	122.3	92.2	0.395
0	1.1	1630	27.16	459.7	16.93	40.4	500	–	–	40.4	–
0	2.3	1593	26.6	443.9	16.69	54.9	500 @ 0.5	675	11.87	43.8	0.181
3	7.8	1146	19.45	396.9	20.72	90.1	500 @ 2.5 / 100 @ 2.6	3850	45.58	44.6	0.405
4	11.8	1093	18.2	373.8	20.54	104.3	500 @ 3. / 120 @ 2.5 / 120 @ 1.8	5250	58.9	45.3	0.427
4	14.7	1027	17.1	359.3	21.0	111.4	500 @ 3.6 / 120 @ 2.5	7000	73.9	37.6	0.481
6	17.3	922	15.4	349.1	22.7	117.1	500 @ 4 / 120 @ 2.5	8350	79.3	37.8	0.476
2	22.6	850	14.2	330.4	23.27	126.1	500 @ 4.5 / 120 @ 2.5	9500	83.2	42.9	0.436
0	27.9	784	13.1	308.3	23.53	130.6	500 @ 5.5 / 120 @ 3.0	11,375	83.8	46.8	0.399
0	28.8	784	13.1	298.5	22.74	126.4	500 @ 6	12,000	80.8	45.6	0.384

Res. of 500. volt motor after tests: Field 308 ω, Armt. 161 ω } 469. Temp on field 95°F, air 68°F } Rise 30°F.

500. motor driving C & C. large 6. bladed fans makes 1170 rpm. & takes 0.2067. 103 w

Experimental Researches on Magnetism.

1st Owing to the rotation of the plane of polarisation of light along the lines of stress flux, it has been supposed that the magnetic activity of iron or vacuum consists in a twist or rotation either as a static arrangement or a dynamic whirl. Maxwell's vortex theory is based on this supposition. To test this theory the following experiments were made:-

A plane mirror, or circular disk of silvered glass about 1 cm in diam., was fastened with beeswax to a paper tube and by this supported in a vertical plane between the poles of the large electromagnet (wide pieces

so that the normal to the mirror was parallel to the pole faces, and the center of the mirror was in the center of symmetry of the field. There was about 0.1 clearance between edge of mirror and poles, the latter being about 1.2 apart. The magnet was excited direct from 120 volt mains. By the use of the spectrometer telescope, a fiducial mark distant 20 metres from the mirror had its image examined by a Ramsden eyepiece at 20 metres

The image was marked by the cross wire and excursions looked for when the current in the magnet had its direction reversed. Had any excursion of image representing 0.05 at 2000 taken place it would certainly have been observed, and if it had been only 0.02 in 2000 it would probably have been detected. No such disturbance was noticeable.

2nd A concave mirror of about 1 metre focus was substituted for the plane mirror to avoid the influence of extended surface in diminishing apparent deviation. No better success.

3rd The concave mirror was immersed in a glass chamber containing CS_2 so that the rays had to pass in entering and emerging through some 5 cms of the liquid. Still no deviation.

4th A beam of light passing across the field through the CS_2 with mirror removed, showed no deviation.

5th A small glass prism (equilateral) was supported between the poles

also

and the D line watched in telescope when current applied and reversed. Nothing observed.

6th A plate of glass 10·2 × 8·2 × 0·1 was coated on one side with a film of gold by M. Wolfe. The plate was covered with the coat fairly uniformly over an area 10·2 × 6. The plate was quite translucent, its color being a bluish green by transmitted light. Contact at two opposite points 8·5 apart

was made by a drop of mercury at each and the bare circle of each drop was about 0·7 in diam. Copper wire dipped into the mercury. The plate was held horizontal coated side up, midway between the poles of the magnet separated by 0·85. The res. between electrodes under these conditions was approximately 80,000 Ω. If this represents 8·V × 5 cms. of pure gold, the thickness of the film is 1×10^{-6}. Thomson's estimate of the diameter of a molecule is 10^{-7}, so that it is quite likely that bad contact round the edge of the mercury or partial discontinuities in the film may have made the resistance much greater than that fairly due to its thickness. No change could be detected in the resistance when the magnet was excited. The resistance was never quite steady but it is certain that a change of 3% could have been detected.

7th The film was then mounted on leaden strips supported by a second glass plate, and the two clamped together. The resistance between lead strips was about 23,000 Ω. This was inserted between the lid and the central core of the 2 KW/T transformer which was then wired to the 1100 volts 140 ~ mains. No visible change in resistance took place although the film acted right at across the film. 10% could have been observed in the 23,000 Ω measured. No better success with the plate parallel to transformer cores.

$$\frac{8 \times 2 \cdot 2 \times 10^{-3}}{E_0} = 3 \cdot 0 \times 10^{-7} \times 10^{7}$$

$$\frac{17 \cdot 6 \times 10^{3}}{E_0} = 3 \cdot 0 \times 10^{9}$$

$$\frac{3 \cdot 53}{\varepsilon} = 3 \cdot 0 \times 10^{16}$$

$$\varepsilon = 1 \cdot 173 \times 10^{-16}$$

Cross section of nickel in ring #1 = 3.955 sq: cms

$$\phi = \frac{1.41 \times E \times 10^8}{N \rho} = \frac{1.41 \times 10^8 E}{70 \times 10^6 \times 1.19 \times 10^6} = \frac{1.41 \times 10^4}{62.3} E = 2.27 \times 10^2 E$$

$$= 227 E$$

On the Resistance and Capacity of Telegraph wires in a cable from Jersey City to Elizabeth N.J.

It is proposed to employ #14 B.&S. 0.064" diam: having 4109 c.mils and 13.27 ω per mile @ 20°C. for conductors. allowing 0.0625" (1/16") for thickness of insulation, this gives 0.1891 for the whole wire $\therefore D/d = 2.95$ $\log D/d = 1.0$

$2.44 = 0.4622 \times 0.1788 = 0.0826 \times 3 = 0.248$ ℔ per mile.

If # 10 B.&S. wire were used, 1D.1019" diam: having 10,384 c. mils and 5.25 ω per mile @ 20°C. the capacity would be somewhat increased.

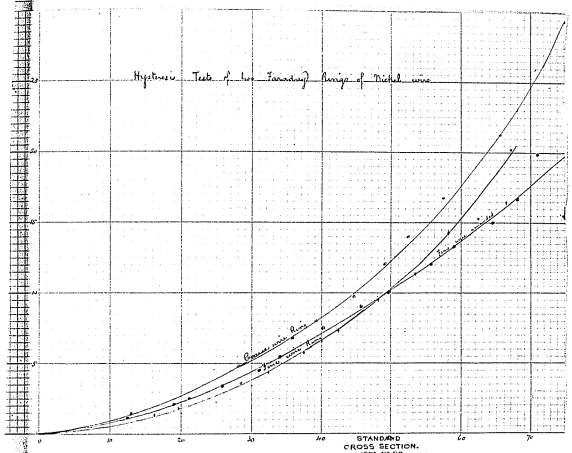
Measurements of Hysteresis in Nickel as detailed on the following page.

The two rings of nickel wire already heated see pp 20 and 29 were measured again. The results are plotted in the two black curves. The upper one accords with the law $H = \alpha B^{\frac{1}{3}}$, but the lower one does not. This agrees with the previous tests. On examination, the second ring was unwound. It was discovered that the bare nickel wire bands were parcelled with a few turns and this might readily introduce currents and absorb energy. The parcelling turns were taken out, and the ring rewound with 605 turns of the same wire. The third series and the upper red line indicate the results which now accord with the $H = \alpha B^{\frac{1}{3}}$ law.

Particulars of 1½ 200 KWT generator at work in the 26th Street Station 12th March 92.

Outside diameter of body	83.5"
Inside " "	75.5"
Length of body) over disks	14.25"
Armatures winding	1008 bars
Cross section per bar	235 × 305 mil
Field winding	169 lbs. of # 15 B+S. per core
Turns per core	4460
Resistances per cores	5H.44 ohms.
Cores to be connected in parallel	
Field to have a total resistance of 6 ω	
and a maximum current capacity of 31 amperes.	

No. of Obs.	Deflection	α	R.	Watts in coil	θ	θ^2	$\frac{\theta^2}{R}$ watts per coil per 1°	γ	$\gamma^{\theta^2 r}$
1	33°	$2 \cdot 365 \times 10^{-6}$	2007	1·567	13	169	0·0831	—	3·12
2	69·5°		"	3·30	21·4	458	0·228	0·1?	
3	110·5°		"	5·246	28·6	818	0·4108	0·15?	
4	163·5°		"	7·761	36·8	1354	0·675	0·3	
5	192		"	9·116	40·2	1616	0·805	0·33	
6	237·5		"	11·28	45·7	2088	1·040	0·39	3·36
7	274		"	13·06	50·3	2530	1·261	0·42	3·20
8	163°		4012	15·47	53·8	2894	0·721	0·47	3·26
9	198·5		"	18·84	59·2	3505	0·873	0·57	3·36
10	266		"	25·24	68·7	4720	1·176	0·92	3·36
11	293·5		6081	49·20	81·5	6642	1·090	1·85	3·36
12									
1	32·5°		2007	1·543	17·6	310	0·155	—	
2	43·5°		"	2·065	21·5	462	0·230	—	
3	56·5°		"	2·707	32·1	1030	0·513	0·1?	
4	108°		"	5·127	36·7	1347	0·671	0·15?	
5	142		"	6·740	43·	1849	0·921	0·2?	
6	183		"	8·688	49·5	2450	1·221	0·25?	
7	240		"	11·395	57·5	3306	1·647	0·35	2·062
8	294·5		"	13·98	64·5	4160	2·073	0·54	"
9	180		4012	17·08	72·2	5213	1·300	0·86	"
10	202·5		"	19·22	77·6	6022	1·50	1·10	"
11	229·5		"	22·73	82·6	6823	1·70	1·50	"
12	318·		"	30·17	87·5	7656	1·908	1·96	2·062
1	25·5°	$2 \cdot 365 \times 10^{-6}$	2007	1·21	12·5	156·	0·077	—	1·811
2	48			2·28	19	361	0·180	—	1·82
3	77·5			3·68	25·9	671	0·334	—	1·83
4	105			4·98	31	961	0·479	0·1	1·84
5	128			6·08	34	1156	0·576	0·15	1·85
6	154		4012	7·97	40·25	1620	0·8074	0·2	1·86
7	182·5			9·724	45·7	2088	0·521	0·3	1·87
8	116			11·01	49·75	2480	0·618	0·36	1·69
9	140			13·28	56	3136	0·782	0·49	1·89
10	157			14·90	59·5	3540	0·882	0·62	1·90
11	196			17·65	66	4356	1·086	0·9	1·91
12	216·5			20·52	70·5	4970	1·239	1·21	1·92
13	231			22·21	74·5	5700	1·421	1·64	1·93
14	296·5			28·13	78·	6084	1·517	1·97	1·935



Measurements of Hysteresis in Nickel May 15

Two nickel wires (Faraday Ring already) referred to on pp. 20 + 29 were Hoopd as before. The corrections were those on pages 20.

H	J^r watts	$J^{r+1} + \frac{a^2}{R}$	Watts in nickel.	$\frac{dJ}{dH}$ in megacurves	Ra	φ	B	c.c.	Ergs per c.c. per cycle
-		0·0814	1·1483	13	$4{\cdot}747\times10^{-3}$	2950	774·6	253·1	41·37
312	0·031	0·289	5·841	21·1	-	4790	1210	$\times 11{\cdot}46$	84·814
468	0·092	0·478	4·768	28·1	-	6377	1612	$= 3{\cdot}553\times10^{5}$	133·1
936	0·308	0·956	6·805	35·9	-	8148	2060		189·9
·03	0·340	1·145	7·971	39·2	-	8896	22·50		222·5
·20	0·456	1·496	9·78	44·5	-	10,100	2554	$\times 4{\cdot}43\times10^{-8}$	273·
344	0·564	1·825	12·135	49·0	-	11,120	2812		338·6
·532	0·720	1·4441	14·03	52·3	$9{\cdot}488\times10^{-3}$	11,870	3000	$=1{\cdot}4433\times10^{5}$	391·5
1·983	1·17	2·040	16·80	57·2	-	12,980	3280		468·7
3·89	2·854	4·016	21·22	65·6	-	14,890	3765		592·1
6·21	11·149	12·58	29·62	75·3	14·38 -	17,090	4320		826·14
-	-	0·155	1·388	16·2	$4{\cdot}747\times10^{-3}$				
-	-	0·230	1·835	19·7	-				
0·206	0·021	0·534	3·573	28·6	-				
0·309	0·046	0·717	4·410	32·3	-				
0·412	0·082	0·903	5·737	37·3	-				
0·516	0·129	1·350	7·338	42·2	-				
0·722	0·253	1·900	9·495	48·0	-				
1·114	0·602	2·675	11·305	53·2	-				
1·774	1·526	2·826	14·254	58·0	-				
2·268	2·495	3·995	15·225	62·4	$9{\cdot}488\times10^{-3}$				
3·093	4·640	6·340	16·39	66·2	-				
4·062	7·924	9·832	20·34	67·2	-				
-		0·08	1·13	12·5	$4{\cdot}747\times10^{-3}$	3284	828·6	$\times 3{\cdot}553\times10^{5}$	34·88
-		0·18	2·10	19		4991	1259	$6{\cdot}344\times10^{-8}$	58·66
-		0·33	3·35	25·9		6804	1717	$6{\cdot}134\times10^{-8}$	93·56
-		0·50	4·48	31·		8144	2055	$6{\cdot}26\times10^{-8}$	135·1
0·18	0·02	0·52	5·46	34		8932	2253	$6{\cdot}55\times10^{-8}$	152·4
0·28	0·04	0·62	7·50	40·18	$9{\cdot}488\times10^{-3}$	10,560	2664		204·4
0·37	0·07	0·47	7·50	44·53		11, 960	3017	$6{\cdot}83\times10^{-8}$	252·6
0·56	0·17	0·69	9·03	45·53		13,010	3282	$6{\cdot}70\times10^{-8}$	253·0
0·68	0·25	0·87	10·14	49·5		14,590	3681	6·62	336·0
0·94	0·46	1·24	12·04	55·54		15,450	3897	5·95 -	371·2
1·13	0·71	1·59	13·31	58·79		16,940	4273		419·5
1·70	1·53	2·62	15·03	64·47		17,970	4538		466·9
2·30	2·57	3·81	16·73	68·0		18,470	4660		438·9
3·17	5·20	6·62	18·57	70·3		18,710	4720		553·7
3·62	6·77	8·29	19·84	71·23					

Results of measurements made by Mr A. O. Tate of the current strength on all the telegraph wires entering the Toronto office of the great Northern Telegraph Co: Mar. 32.

Sixty one measurements were made by Mr Tate of the working current on as many different circuits, taking a milliampire meter and inserting it at the switchboard. The sum of the 61 readings was 1.215 amp: representing an average of 0.020 amp to each circuit. These are all worked on the closed circuit plan, a few are worked duplex. They vary in length from 333 to 1 mile and a fair proportion are batteried at other stations in circuit. The maximum measured current was 0.10 (not included in the average) for a City Gold & Stock circuit. Next to that was one line taking 0.045. The minimum was 0.012 observed in one case and next to that 0.018 in several cases. 0.020 is a fair average for all lengths in ordinary weather. Forty nine circuits were operated from 12 Gaillard batteries varying from 90 to 132 cells each. The maximum calculated p.d. at battery terminals being 128 volts and the minimum 58 v. The total number of cells in use was 1117 averaging 100 cells each (besides one Edison Lalande battery of 2 cells that works 16 other circuits). The cost of these Gaillard cells is from 48 ¢ to 53 ¢ per cell per annum in material. At 50 c - $6.00. There is thus an average of 14 circuits to the battery or 25 cells to the circuit. The maximum current supplied from any one battery was 0.110 A.

Estimates on Electric Lighting Work.

Costs of laying in Cities obtained from Mr Sewell 21st Mar.:

Laying + Testing	Mains	18 ¢	per running foot
" " "	Feeders	23 "	" " "
Trenching + filling either		50 "	" " " of each.

In houses, the average number of lamp outlets is rather more than 1/3rd of the number of lamps, or nearly 3 lamps per outlet. The cost of labor for wiring is commonly 2 ¢ per running foot for moulding work.

Estimated List Price of ¢400 KW. dynamos obtained from Schenectady.

Safe List Price	$ 37,000 each
Ammeter -	100
Volt indicator -	75
	$ 37,175 -

Weight of dynamos + engines in multipolars

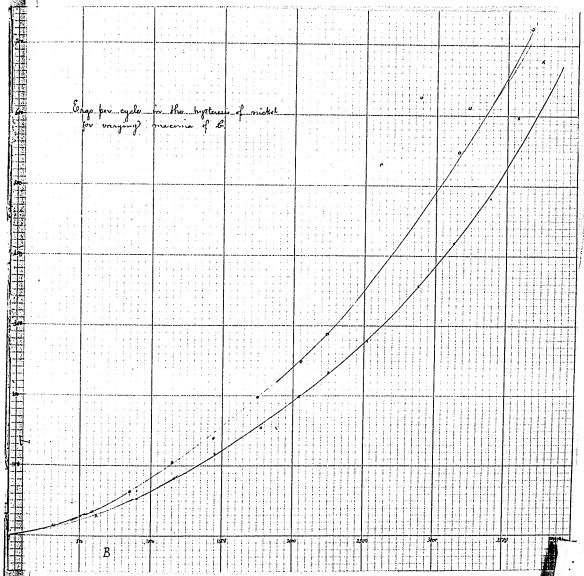
100 KW. dyn:	25,000 lbs. each
200 " "	44,000 " "
400 " "	75,000 " "
2 X 100 KW Engine	75,000 lbs.
2 X 200 " "	175,000 "
2 X 400 " "	360,000 "

Costs of operating dynamos only in Central Stations.

Item											
Mar 32											
" 2	24 @ 60 KW.	= 1440	-	1	-	-	24	-	168	-	$60 = 11.13
" 3	14 @ 100	= 1400	-	1	-	-	2	-	-	-	$45 = 7.05
" 12	12 @ 100	= 1200	-	1	-	-	2	-	-	-	$45 = 3.90
" 5	8 @ 100	= 800	-	1	-	-	1	-	-	-	$ 36.75 = 2.60
" 6	20 @ 60	= 1200	-	1	-	-	4	-	-	-	$ 106 = 8.83

Ring #1 570 turns of nickel wire #19 B&S weighing 0.0365 lb or 0.0927 in diam.
Section of wire 6.7×10^{-3} sq"
Mass of wire 2.255 gms. Soaked in melted paraffin wax
Volume " 253 c.c.
Int. diam 52.5 cm. Mean 63.75 Mean 206.8
Mean cross section of ring 3.852 by cor. diameter
" " " 3.848 " number of turns
Winding 700 turns of #22 B&S wire layer.

Mark No	Degrees θ_2	α	R	Rc	R at Watts in cct.	e	e'	e'/R	γ	f
1	24°	2.365×10^{-5}	1007	2.381×10^{-5}	0.571	5.5	30.25	0.030	–	3.05
2	57	"	"	"	1.357	10	100	0.099	–	"
3	105.5	"	"	"	2.512	14.5	207.4	0.206	–	"
4	84		2007	4.746	3.987	20	400	0.199	0.15	"
5	115		"	"	5.457	25	625	0.312	0.2	"
6	107		3007	7.112	7.61	20.5	930.3	0.309	0.25	"
7	135.5		"	"	9.036	35.8	1281.6	0.426	0.3	"
8	159		"	"	11.24	38.9	1513.2	0.503	0.36	"
9	211		4007	9.476	20.0	45.5	2070.	0.517	0.44	"
10	253		"	"	23.98	50.5	2550.	0.636	0.55	"
11	234		"	"	22.18	56.0	3136	0.783	0.75	3.10
12	271		"	"	25.69	61.4	3770	0.941	0.95	3.12
13	291.5		5700	1.230×10^{-4}	31.3	66.	4436	0.853	1.20	3.14
14	310		"	"	36.12	71.3	5084	0.978	1.60	3.18
15	135		3007	7.112×10^{-5}	9.60	35.5	1260	0.419	0.30	3.15
1	23.5		1007	2.381×10^{-5}	0.567	5.5	30.25	0.030	–	2.35
2	49.5		"	"	1.179	10.5	110.25	0.1095	–	"
3	88		"	"	2.096	15.2	231.0	0.229	–	"
4	66.5		2007	4.746	3.156	20.	400	0.199	0.1	"
5	98		"	"	4.652	25.7	660.5	0.329	0.15	"
6	84		3007	7.112	5.975	30.5	930.3	0.309	0.2	"
7	110		"	"	7.822	35.4	1253.2	0.417	0.3	"
8	124		"	"	9.174	39.1	1529	0.589	0.33	"
9	115	"	4007	9.476	10.9	43.8	1918	0.479	0.38	"
10	152.5		"	"	14.45	50.5	2550	0.636	0.60	"
11	193		"	"	17.34	55.4	3069	0.766	0.82	"
12	234		"	"	22.18	60.8	3697	0.923	1.18	2.85
13	239		5800	1.23×10^{-4}	29.4	65.0	4225	0.812	1.85	2.87
14	290		"	"	35.67	69	4761	0.915	1.90	2.89
15	110		3007	7.112×10^{-5}	7.922	35.5	1260	0.419	0.3	"



Hysteresis measurements with Nickel contd. Mar. 18th

Coil # 2. 4160 turns of nickel wire # 26 B&S. 0.0126" (0.032)

Value of wire 8.014 X 10⁻⁶ cm²

Mass of wire 2255 gms. Soaked in melted paraffin wax

Volume 253.3 c.c.

D.I. wire: 53.5° Ext. 78. Mean 65.75°

Mean cross section of ring 3.85 sq. ins. by dimensions of ring
3.345 " by number of turns & area of wire.

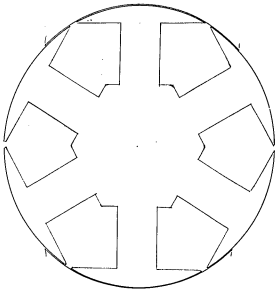
Winding 700 turns of # 22 B&S. cow tape.

I'	I'r	I'r + C/R	Watts in Nickel.	Ind. density in Nickel.	Φ 227 (μ)	B Φ/3.85	wb x 10⁸ 253.3/10⁸	F megilbers per sq. cm.	η
3.05	–	–	0.03	0.574	5.5	1249	324.4	3.586 x 10⁻⁶	15.06	
	–	–	0.10	1.26	10	2271	590		35.18	
	–	–	0.21	2.30	14.55	3295	855.8		64.13	0.0013814
0.45	0.07	0.27	3.72	19.55	4.1440	1153			103.7	
0.61	0.12	0.43	5.03	24.39	5539	1439			140.3	
0.76	0.19	0.50	7.11	29.74	6754	1754			198.3	
0.92	0.28	0.71	8.93	34.88	7922	2058			249.0	0.0012443
1.10	0.40	0.90	10.34	37.80	8584	2230			288.3	0.0012666
1.34	0.57	1.01	18.99	44.16	10,030	2605			529.5	
1.68	0.92	1.56	22.42	48.82	11,090	2880			625.1	
2.33	1.75	2.53	19.65	53.67	12,190	3166			547.9	
2.96	2.81	3.75	21.94	58.44	13,270	3446			611.8	
3.77	4.53	5.38	25.92	62.23	14,140	3673			722.6	
5.09	8.14	9.12	29.0	66.21	15,040	3907			808.5	
2.95	0.29	0.71	8.89	34.55	7,846	2039			247.9	
–	–	0.03	0.574	5.5	1249	324.4			15.06	
–	–	0.11	1.07	10.5	2,384	619.2			29.83	
–	–	0.23	1.87	15.2	3,452	896.5			52.13	
1.28	0.03	0.23	2.93	29.72	4.479	1164			81.68	0.0016015
1.42	0.06	0.39	4.26	25.28	5,741	1491			118.8	
1.56	0.12	0.42	5.56	29.94	6,800	1766			155.1	
1.84	0.25	0.67	7.15	34.56	7,848	2039			199.4	
2.03	0.31	0.52	9.35	38.97	8,668	2252			232.8	0.001011
2.08	0.42	0.90	10.0	42.72	9,702	2520			278.8	
2.68	1.01	1.65	12.8	48.82	11,090	2881			356.9	
3.33	1.91	2.68	14.66	53.07	12,050	3130			408.7	
3.86	3.96	4.89	17.30	57.44	13,050	3390			482.4	
4.54	7.17	7.98	21.42	60.46	13,730	3566			597.2	
5.49	10.43	11.35	24.32	62.51	14,430	3748			678.2	
2.54	0.26	0.68	7.14	34.63	7,864	2043			199.1	

Coarse wire ring

Fine wire ring

Design for a Battery Fan Motor of simple and cheap construction.



Power	=	5 watts
Speed	=	900 r.p.m.
Battery employed	=	4 cells of Edison-Lalande Battery 300-amp-hr type.
EMF	=	2.8 volts.
Current	=	4 amps
Res. of battery	=	$4 \times 0.05\Omega = 0.2\Omega$
Drop in battery	=	0.8 volt
P.D. at battery terms.	=	2.0 "
P.D. at motor terminals	=	1.9 "
EMF of motor	=	1.3 "
Flux "	=	20,000
Number of wires	=	120. or 70 in each limb
Armature type	=	Bar limbed.
Cross. section of limb	=	$1.5" \times 1.5" = 2.25$
Effective " "	=	2.0 sqr. cms.
Polar surface "	=	$5" \times 1.5" = 7.5$ cms^2
Entrefer	=	$0.020" = 0.05$ cms.
Air reluctance	=	$0.1/7.5 = 0.0133$
MMF needed	=	266
A.T. "	=	213
Turns at load	=	53
Core of field magnet	=	Cast iron
Intensity in core	=	6800
Leakage factor	=	1.4
Total armature flux	=	30,000 at successive intervals
" field "	=	42,000
" " section	=	8.4 sqr cms
Diameter of field	=	3.3 cms. = 1.33".
Length of mean armature		0.25"
" " winding	=	10.6'
Res. of motor allowed	=	0.15Ω
" " armature	=	0.08Ω
" " armature wire	=	0.32Ω
Feet per ohm	=	3.30'
Size of wire	=	#17 B.W.G. 0.058" d.c.c. 0.064".
Interplange on arm.	=	$0.85" = \frac{7}{8}$ nearly.
Diameter of field	=	1.33"
Core "	=	4.19" = 0.35'
Length of wire	=	220'
Res. "	=	0.07Ω
Wire	=	0.00035Ω per foot #17 B.W.G. 0.058" d.c.c. to 0.065".
Weight	=	0.2 lbs.

Tests and Particulars of new Edison Model Dial Recording Meters.

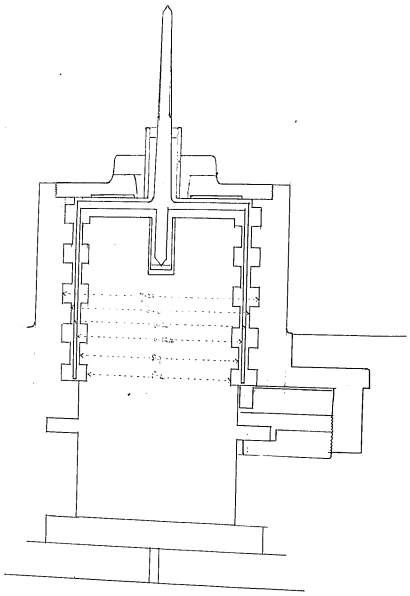
Twelve models were prepared similar to that whose tests and developments have been recorded.

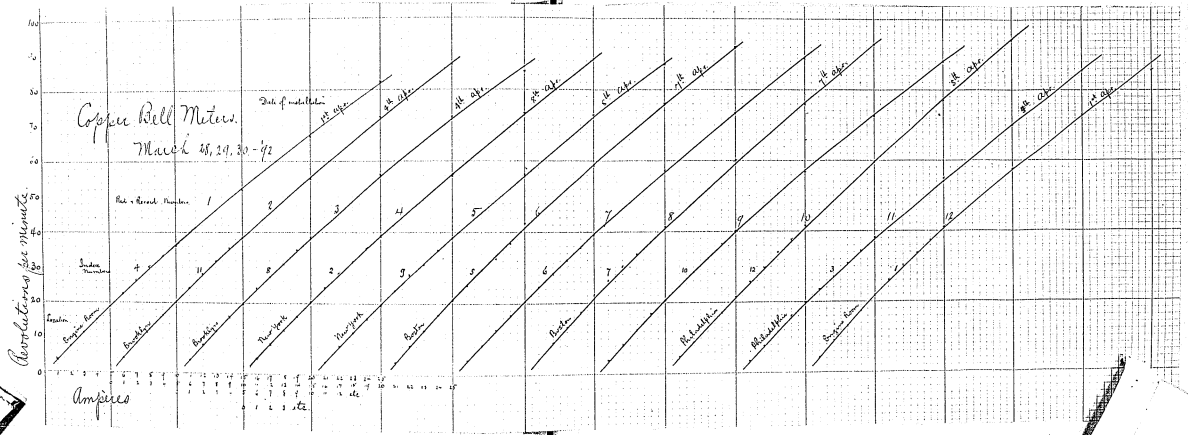
8 meters were sent out

2 to Newyork on the 30th March installed on the 8th Apr.
2 . Brooklyn . . . . . 4th .
2 . Philadelphia . . . . . 5th .
2 . Boston . . . . . 7th .

of these one (sent to Boston did not work properly) and was sent back after installation.

Nos 9 & 11 were set up on 20 lamps steady load 16 hrs. daily on the 9th Apr with amalgamated shafts & bakes at zero.
At 12·30 on the 16th April, the readings were #9 16,6047 #11 16,8514.




Copper Bell Meters.
March 28, 29, 30 - 92
Revolutions per minute
Amperes
Engine Room
Brooklyn
Brooklyn
New York
New York
Boston
Boston
Philadelphia
Philadelphia
Engine Room
1st alt.
2d alt.
3d alt.
4th alt.
5th alt.
6th alt.
7th alt.
8th alt.
9th alt.
10th alt.
11th alt.
12th alt.

Facts ascertained in connection with electric lighting for Chicago and the World's Fair.

The cost of wiring from services to lamp in the World's Fair Buildings including switches, cut-outs, mains, risers, lamp lines, sockets (Keyless) and lamps is $ 2.00 per lamp.
The cost of dynamos of large capacity is $ 3.38 per lamp at list and $ 2.17 at customer's rate, $ 1.33 at Licencees rates.
Insurance for World's Fair reckoned at 1.5 % for 18 months
Cost of coal in Adams St. Station is $ 3.25 delivered per ton
" " prospected $ 2.00 " "
Load in Adams St. station reached 15,000 lamps one day last winter
The previous winter it reached about 12,000 and it is contemplated to reach 20,000 in the coming winter.
The average cost of wiring to the local company is $ 3.00 per lamp installed in ordinary houses.
About $ 100 would be the average cost of wiring a house.
The average return from a house is $ 70 annually.
8 $ 60 s (150 KWTs) and 20 $ 32 s (100 KWTs) are installed.
The 100 KWT machines are not operated above 500 amperes and the 150 KWT " " 1000 " "
Rates are 1/ per lamp hour. 16 cp.

Test of a new plate-holder in the Edison-Lalande cell.

A 100 amp-hr cell was set up on the 25th March in the usual manner except that copper straps were screwed out to the Zinc plate below the surface of the solution, and no oil was used. The weight of each plate was 282 grms. including holder. This weight remained unaltered up to the 9th Apr., and no appreciable local action appeared to have taken place although the junction was underneath the liquid. A film of zinc appeared to be deposited on the copper, up to the level of the surfaces.
The cell was kept at work on 3 amperes during several days. Curves of its behavior were obtained.

Tests of lead in telephone cables sheathing

Seven samples of lead were received for examination and trial from New York

# 1	is pure Edison cold-pressed lead with admixture of 2.0 % bismuth		
# 2	" " " " " " "	1.5 % bismuth	3.40 antimony
# 3	" " " " " " "	1.0 "	
# 4	" " " " " " "	2.6 "	
# 5	" " " " " " "	3.1 "	3.60 antimony 9th to 13th Apr.
# 6	" " " " " " "	0	
# 7	Western Electric hot pressed lead		

These samples were sent to Gideon E. Moore 221 Pearl St. NY. for analysis on the 13th Apr.

The assays of these samples by Gideon E. Moore show

omitted	# 2	1. 1.775
	15	2. 0.011
	1	3. 0.149
	24	4. 2.415
	31	5. 1.880
	0	6. 0
	3	7. 1.721

Measurement of Constants of Dynamometer (Differential Type).

The following tests were taken of the 4 pr new differential dynamometer coils.

No. of Obs.	Coil	Res. @ 26°C	Ind. Millihenry	C. Amp.	e.	Cc	τ	α	Mean α	v	
1	Upper #1	0.0225Ω	0.0225 L	10.568	0.01581	0.16708	136°	1.227×10^{-2}		+0.023	
2	6 turns			13.358	0.01599	0.21359	169.2°	1.261 "		−0.010	1.2516 0.0115 $\times 10^{-3}$
3				13.285	0.0295	0.37662	303°	1.232 "		+0.029	
4				3.426	0.02966	0.10160	78.5°	1.294 "	1.257×10^{-2}	−0.013	
5	Upper #2	0.0388Ω	0.0595 S	1.803	0.01636	0.029497	12.1°	2.37×10^{-2}		+0.781 −0.004	
6	28 turns			0.940	0.13327	0.031274	126.5°	2.472 "		+0.569	2.3832 0.0000 $\times 10^{-4}$
7				2.280	0.03299	0.47522	327°	2.300 "		−0.033	
8				2.295	0.03312	0.078011	319.2°	2.381 "	2.3833×10^{-2}	−0.000 +0.0178	
9	Upper #3	0.934Ω	0.588	0.9005	0.01624	0.0114624	2.85.5°	5.122×10^{-3}		+0.012	5.134×10^{-3}
10	120 turns			0.4523	0.01620	0.007227	141.8°	5.132 "		+0.002	$\pm$ 0.0026
11				0.4502	0.02950	0.01328	251°	5.148 "	5.134×10^{-3}	−0.014 +0.0252	
12	Upper #4	7.111Ω	5.1440	0.2007	0.01643	0.003297	202.8°	1.304×10^{-2}		− 0.003	
13	432 turns			0.1153	0.01611	0.001869	114.4°	1.292 "		− 0.001	1.291 0.000 $\times 10^{-3}$
14				0.1994	0.02010	0.006009	313.5°	1.278 "	1.291×10^{-2}	+0.012 −0.047	
15											
16	Lower #1	–	–	18.79	0.01991	0.37411	87°	4.304×10^{-2}		− 0.001	4.299×10^{-3} $\pm 0.0026 \times 10^{-3}$
17	2 turns			18.726	0.02893	0.524172	126.5°	4.282 "		+ 0.017	
18				18.579	0.03901	0.724177	168°	4.314 "	4.299×10^{-2}	−0.032 +0.031	
19	Lower #2	–	–	11.542	0.01627	0.188914	92°	2.054×10^{-2}		0.007	2.061 ± 0.000 $\times 10^{-3}$
20	12 turns			11.627	0.03123	0.39800	172°	2.073 "		0.012	
21				18.303	0.03113	0.63151	307°	2.057 "	2.061×10^{-2}	0.000 0.012	
22	Lower #3	0.0218Ω	0.0526 S	3.225	0.01632	0.652432	198.5°	2.602×10^{-2}		0.002	2.650 ± 0.000 $\times 10^{-3}$
23	28 turns			1.925	0.01648	0.031666	120°	2.639 "		0.011	
24				2.380	0.03424	0.081611	307°	2.658 "	2.650×10^{-2}	0.007 0.021	
25	Lower #4	0.3578Ω	0.3893	0.4374	0.01617	0.0070727	52.8°	5.526×10^{-3}		0.004	5.535 ± 0.010 $\times 10^{-3}$
26	120 turns			0.909	0.01617	0.014698	265.5°	5.526 "		0.001	
				0.5497	0.0297	0.017811	321.5°	5.543 "	5.535×10^{-3}	0.009 0.018	

Suspended coils # 33 — 0.75 int. Bowls — 2-8 ext. diam., 3.42 long, 0.096 (published) 27 turns of 25 lines

Upper suspension: 19.50 cm, 6.94 h, 0.355 Ω (19.57 Temp.)

Weight of each coil 30 gms approx.

Lower suspension: 17.75 cm, 6.41 h, 0.360 Ω (19.57 Temp.)

Weight of coil with sup system about 65 gms

Diameter of copper suspension wire 0.004". (0.0115 cm) Length 32.5 cm

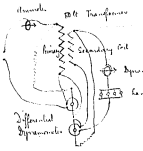
Torsional modulus of a sample of wire from the same stock

Length 26.398 cm. with copper sphere 2.82 diam = 1.27 radi. Mass 76.25 gms I = 44.18

Observed periodic time 9.205 secs.

Torsional modulus = $\frac{44.18 \times 26.4 \times 4\pi^2}{9.205^2 \times 4.343} = 605$

Torsional moment for working wire = 605 / 32.592 = 18.57 cm. dynes for unit deflection.



Transformer Tests with Differential Dynamometer.

The differential dynamometer was connected up as shewn on the opposite page. It was found that the direct passage component of the fixed coils affected the suspended opposite coils, This influence was only noticeable at or near full load current strengths but then amounted to several degrees of torsion. It was however quite possible to arrange the fixed coil lead so that this influence annulled this error, without altering the constants of the upper or lower suspensions.

The two constants were brought into equality by passing a current from a transformer secondary through the two fixed coils in series, and placing such resistances in the suspension circuits independently operated from the 120 volt secondary terminals that no deflection was observed on opening or closing the circuit.

These resistances of the suspension circuits that produced balance were Lower coil 1337 Lower coil 2267

Upper - 19,818 Ratio 8.838 ; and Upper - 19,940 Ratio 8.796

The transformer employed was the 80 kilo. Edison experimental transformer for whose design and modifications see Book V. p 111 & 118

The resistance of the primary at start was 1.29 ω and during test taken at 1.34 ω

- - - - secondary - - - 0.0305 ω - - - - - 0.038 ω

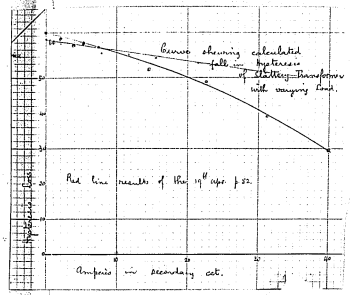
The following readings were observed. 8/10. 93.

Coils used were Upper # 2 in primary ckt. Lower # 2 in secondary.

No. of Obs.	Torsion	Pri. amp.	Pri. amp. Rev.	Secondary Current Upper #1	Amperes in Antiphase Current	Volts at Secondary terminals	Amperes Lost	Rev. in coil susp. ckt.		Constant K	Energy lost in Transformer	% Loss	Energy Input in Primary	Watts
1	147.5°	0.5		11,818 ω	-	120	-	1337		2.7855	406	0.35	406	313
2	144.2	0.78		7.5° fwd	2.51	120	6				391	1.09	390	297
3	144.2	1.05		32° "	5.13	119	12				391	2.54	388	295
4	146	1.5		87° "	8.53	118.5	20				402	5.90	396	303
5	150	2.81		41° rev	19.30	116.5	49				413	25.21	388	295
6	158	4.06		97° "	29.7	111.5	76				435	56.6	378	285
7	167.5	4.86		114.5° "	36.31	113.5	95				461	73.7	387	294
8	146.5	0.5		0		120	-				402	0	402	311

The rate of hysteretic loss was also determined as follows:-
Upper dynes only in use.

Current	No. of Obs.	Secondary volts	ν	Ke	Loss in Transformer	- S/ν
2.5	1	122	142.5	2.7855	392.7	300
"	2	118.5	139.5	"	384.4	291.4
"	3	112.8	128.0	"	352.7	259.7
"	4	109.2	118.5	"	326.5	233.5
"	5	107.5	120.	"		
"	6	105.2	117	"	322.4	229.4
"	7	102.3	111.5	"	307.2	214.2
"	8	100.	109.	"	300.3	207.3
"	9	98.	105.	"	289.3	196.3


Curve showing calculated fall in hysteresis of Stanley-Transformer with varying Load.
Red line records of Plate 19 page p 82.
Amperes in secondary cct.

Transformer Tests with Differential Dynamometer 11th Apr.

Slatterly Transformer. 30 light 1000 – 50.
Coil on dynamometer ♯2 upper in primary ckt. ♯2 lower in secondary.
Res. of transformer coils Primary before test 9.38ω after test 10.4ω
Secondary " " 0.0844ω " " 0.094.4ω

Coil compensated for mutual influence at full load, and compensation checked after test.

Compensated balances of suspension ckt: resistances with fixed coils in series 3739ω in parts secondary 19.500ω in primary ckt. E/r = 56.8

	7	P.D. at Sec. term.	Sec. Dyn. Scale ♯1	Sec. current m.a.	Primary current m.a.	50 watt lamps in ckt.	Re	∂R	∂X	Primary in lamps	Watts $C^2R_1 + E/r$	Hysteresis
	119.5	52.5	0	0	0.2	0	1.001	0.4	0	119.6	66.9	62.7
	118.5	"	6°	2.241	0.3	4		0.9	0.2	118.6	57.6	61.0
	119.0	51.9	0	0	0.2	0		0.4	0	119.1	56.9	62.2
	118.0	"	36.5	3.717	0.38	6		1.2	0.6	118.1	58.3	59.8
	119.0	"	0	0	0.2	0		0.4	0	119.1	56.9	62.2
	118.0	"	32°	5.177	0.36	8		1.4	1.2	118.1	59.1	59.0
	119.6	52.3	0	0	0.2	0		0.4	0	119.1	56.9	62.2
	119.5	51.5	69°	7.60	0.49	12		2.5	2.5	119.6	61.5	58.1
	118.5	52.0	0	0	0.2	0		0.4	0	118.6	56.9	61.7
	123.7	50.9	253°	14.55	1.88	24		7.0	9.3	123.8	72.8	51.0
11	118°	52	0	0	0.2	0		0.4	0	118.1	56.9	61.2
12	145°	50	56° comm	22.56	1.32	40		18.28	22.3	145.1	97.1	48.0
13	119.5	52.3	0	0	0.2	0		0	0	119.6	56.9	62.7
14	170.5	44.1	109° "	31.33	1.77	55		82.85	43.1	174.6	15.9	62.7
15	121.5	52.5	0	0	0.2	0		0	0	121.6	56.9	64.7
16	208.5	48.2	175.3	3.7.12	2.22	76		50.7	70.0	208.7	177.2	31.5

Experiments on the Chemical corrosion of lead sheathing on Telephone Cables.

Telephone cable specifications call for 3 % of tin alloyed with the lead in cable sheathing. It was discovered, accidentally perhaps, that when two leaden cables lay in the same wooden trough, one of ordinary lead, the other having 3% of tin, the latter resisted corrosion much more successfully. These were hot-press lead sheathings. Since that time the 3% has been insisted upon. There is as yet no evidence upon the behavior of Schenectady lead cold press sheathing and their longevity. It was found on trial at Schenectady that 1.5% of tin could be used without great difficulty, but 3 % made the metal so hard that it could not be handled in the cold press.

In order to ascertain the amount of lead existing in Western Electric cables sheathing, a short piece was obtained, and sent with some other samples of Schenectady alloys to G. E. Moore the newyork analyst see p 48.

Twenty samples of lead from Schenectady with 1.5% tin, and twenty samples of Western Electric lead, all having the same dimensions 3.12 X 1.6 were cut to gauge, filed, and weighed. They were then immersed each in a separate solution.

No. of plate		Solution		Weight Apr. 14th	Weight apr. 16th	Weight apr. 22nd	Weight apr. 16th	Weight apr. 18th	Weight apr. 22nd
1	21	5% Acetic acid in	H_2O	15.521	15.523 (+.002)	15.523	19.525	19.527	19.529 (+.002)
2	22	5% Benzoic	"	17.306	17.312 (+.006)	17.316 (+.004)	18.132	18.130 (−.002)	18.132 (+.002)
3	23	5% Worm Tar oil	"	14.258	17.263 (+.005)	17.272 (+.009)	17.044	17.040 (−.004)	17.038 (−.002)
4	24	250 c.c. dist. H_2O containing CO_2		17.521	17.520 (−.001)	17.521	17.962	17.961	17.962 (+.001)
5	25	250 c.c. K_2CO_3 sat. sol.		17.587	17.585 (−.002)	17.587	17.913	17.911	17.915 (+.002)
6	26	5% H_2SO_4 in	H_2O	17.684	17.688 (+.004)	17.689	17.223	17.230 (+.007)	17.231 (+.001)
7	27	5% acetic acid in	H_2O	17.551	17.548 (−.003)	17.554 (+.006)	18.930	18.930 (0.000)	18.870 (−.060)
8	28	1% HNO_3	"	17.249	17.250 (+.001)	17.245 (−.005)	19.132	18.838 (−.294)	18.673 (−.165)
9	29	5% NH_4S	"	17.303	17.301 (−.002)	17.304	18.865	18.868 (+.003)	18.869 (+.001)
10	30	5% NH_4SO_3	"	16.423	16.419 (−.004)	16.420 (+.001)	19.063	19.064 (+.001)	19.062 (−.002)
11	31	5% $NH_4(HO)$	"	17.521	17.503 (−.018)	17.492 (−.011)	18.739	18.726 (−.013)	18.708 (−.018)
12	32	5% NH_4SO_4	"	17.599	17.602 (+.003)	17.606 (+.004)	18.239	18.246 (+.007)	18.247 (+.001)
13	33	5% Alum	"	17.642	17.638 (−.004)	17.640 (+.002)	18.204	18.206 (+.002)	18.206 (0.000)
14	34	Crude Carpet cone.		17.593	17.582 (−.011)	17.578 (−.004)	19.180	19.182 (+.002)	19.183 (+.001)
15	35	5% HCl	"	17.680	17.668 (−.012)	17.439 (−.229)	18.242	18.214 (−.028)	18.210 (−.004)
16	36	5% Bartholet of Soda	"	17.4462	17.431 (−.015)	17.433 (+.002)	17.986	17.980 (−.006)	17.980 (0.000)
17	37	5% NH_4HO	"	17.253	17.247 (−.006)	17.249 (+.002)	19.149	19.150 (+.001)	19.152 (+.002)
18	38	5% NH_4Cl	"	17.537	17.533 (−.004)	17.531 (−.002)	18.695	18.701 (+.006)	18.707 (+.006)
19	39	5% Na_2Cl	"	16.388	16.390 (+.002)	16.393 (+.003)	18.892	18.894 (+.002)	18.894 (0.000)
20	40	5% sol. of Dr. Soxhlet's Milk Powder		16.423	16.423	16.425	17.400	17.402	17.401 (−.001)

No. of plate	Weight 26th	Weight 3rd May	Weight 16th May		No. of plate	Weight apr. 26th	Weight 3rd May	Weight 16th May
1	15.523	15.524			21	18.530	15.530	
2	17.237 (+.004)	17.226 (−.011)			22	18.132 (−.014)	18.116 (−.016)	
3	17.401 (+.011)	17.391 (−.010)			23	17.030 (−.013)	17.027 (−.003)	
4	17.520 (−.001)	17.521 (+.001)			24	17.964 (+.002)	17.962 (−.002)	
5	17.588 (+.003)	17.586 (−.002)			25	17.914 (+.001)	17.914 (0.000)	
6	17.689 (+.005)	17.690 (+.001)	17.690 (0.000)		26	17.231 (+.003)	17.231 (0.000)	17.231 (0.000)
7	17.548 (−.003)	17.549 (+.001)			27	18.852 (+.062)	18.790 (−.062)	
8	16.825 (−.424)	16.817 (−.008)			28	18.783 (−.049)	18.822 (+.039)	
9	17.302 (−.001)	17.304 (+.002)	17.300 (−.004)		29	18.868 (−.001)	18.869 (+.001)	18.865 (−.004)
10	16.420 (−.003)	16.407 (−.013)			30	19.082 (+.019)	19.055 (−.027)	
11	17.474 (−.017)	17.470 (−.004)			31	18.656 (−.083)	18.636 (−.020)	
12	17.606 (+.001)	17.606 (0.000)	17.607 (+.001)		32	18.248 (+.001)	18.247 (−.001)	18.247 (0.000)
13	17.639 (−.003)	17.642 (+.003)	17.644 (+.002)		33	18.209 (−.001)	18.210 (+.001)	18.212 (+.002)
14	17.580 (−.013)	17.585 (+.005)	17.588 (+.003)		34	19.181 (−.001)	19.182 (+.001)	19.181 (−.001)
15	17.638 (−.042)	17.627 (−.011)	17.628 (+.001)		35	18.218 (−.024)	18.222 (+.004)	
16	17.430 (−.032)	17.420 (−.010)			36	17.979 (+.002)	17.977 (−.002)	
17	17.248 (−.005)	17.249 (+.001)	17.248 (−.001)		37	19.151 (−.001)	19.151 (0.000)	19.151 (0.000)
18	17.523 (−.014)	17.515 (−.008)	17.513 (−.002)		38	18.699 (+.004)	18.691 (−.008)	18.689 (−.002)
19	16.392 (−.001)	16.393 (+.001)	16.386 (−.007)		39	18.893 (+.001)	18.892 (−.001)	18.891 (−.001)
20	16.421 (−.002)	16.420 (−.001)			40	17.398 (−.003)	17.396 (−.002)	

On the 16th the apparent corrosion was as follows:—

20	bad	40	bad
18 + 4	distinct	38, 28, + 24	distinct
10	marked	26	marked
11, 9, 11	slight		

They were removed, dried, weighed and replaced on the 18th

Tests for Corrosive Action of Lead contd.

(50)

Twenty more plates were cut from good Schneetady lead annealed, and were superficially coated with sulphate before drying and weighing by immersing in strong H_2SO_4.

No. of Plate	1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	11th day.	12th day.	13th day.	14th day.	15th day.	16th day.	17th day.	18th day.	19th day.	20th day.
1	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715	22.715
2	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991	20.991
3	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946	21.946
4	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436
5	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735	21.735
6	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436	22.436
7	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970
8	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890	24.890
9	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970	21.970
10	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320	21.320
11	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940	24.940
12	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
13	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66	21.66
14	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760	21.760
15	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060	23.060
16	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934	24.934
17	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460	25.460
18	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640	26.640
19	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970	25.970
20	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358	25.358

These 20 plates were then immersed in distilled water, as before on the preceding page.

As it is mentioned in a text-book on Alkali that lead is readily corroded by water containing free CO_2, the lead carbonate being soluble in such liquid, and also that it is corroded by an aqueous solution of acetic acid, it was decided to try these two liquids specially.

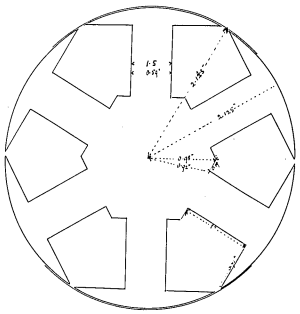
8 plates were cut as follows.

2 of pure Schneetady lead in CO_2 water + 2 do: in 5% acetic acid
2 . Solder bar from storeroom . . . . 2 . . 5% . .

No. of Plate	Metal	Stamped	Solution	Weight 16th Apr.	Weight 21st Apr.	Weight 25th Apr.	Weight 13th May.	
1	Solder	41	5% Acetic acid in H_2O	22.955	22.941 .014	22.927 .028	22.872 .083	
2	"	42	Saturated CO_2 water 20m	16.535	16.597 .062	16.530 .067	16.525 .072	
3	Lead	41	5% Acetic acid in H_2O	27.370	27.330 .040	27.323 .047	27.320 .050	
4	"	42	Saturated CO_2 Water	25.930	25.930 .000	25.924 .006	25.920 .010	
5	Solder	41a	50% Acetic acid H_2O	12.295	12.279 .016	12.265 .030	12.167 .128	
6	"	42a	Saturated CO_2 water	7.640	7.636 .004	7.634 .006	7.630 .010	
7	Lead	41a	50% Acetic acid H_2O	26.920	26.840 .080	26.783 .137	26.585 .335	
8	"	42a	Saturated CO_2 water.	29.120	29.070 .050	29.023 .097	28.895 .225	

Twenty more plates were cut from good Schneetady lead annealed and were superficially cleaned weighed and immersed on the 19th inst. in company with those on the top of this page.

No. of Plate	Weight 19th Apr.	Weight 21st Apr.	Weight 23rd Apr.	Weight 25th Apr.	Weight 27th Apr.	Weight 29th Apr.	Weight 1st May.	Weight 3rd May.	Weight 5th May.	Weight 7th May.	Weight 9th May.	Weight 11th May.	Weight 13th May.
1	12.880	12.875 .005	12.874 .006	12.868 .012	12.866 .014	12.864 .016	12.863 .017	12.862 .018	12.861 .019	12.860 .020	12.859 .021	12.858 .022	12.857 .023
2	13.320	13.315 .005	13.314 .006	13.308 .012	13.306 .014	13.304 .016	13.303 .017	13.302 .018	13.301 .019	13.300 .020	13.299 .021	13.298 .022	13.297 .023
3	13.090	13.085 .005	13.084 .006	13.078 .012	13.076 .014	13.074 .016	13.073 .017	13.072 .018	13.071 .019	13.070 .020	13.069 .021	13.068 .022	13.067 .023
4	13.220	13.215 .005	13.214 .006	13.208 .012	13.206 .014	13.204 .016	13.203 .017	13.202 .018	13.201 .019	13.200 .020	13.199 .021	13.198 .022	13.197 .023
5	13.210	13.211 .005	13.210 .006	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000	13.210 .000
6	12.890	12.885 .005	12.884 .006	12.878 .012	12.876 .014	12.874 .016	12.873 .017	12.872 .018	12.871 .019	12.870 .020	12.869 .021	12.868 .022	12.867 .023
7	13.370	13.365 .005	13.364 .006	13.358 .012	13.356 .014	13.354 .016	13.353 .017	13.352 .018	13.351 .019	13.350 .020	13.349 .021	13.348 .022	13.347 .023
8	13.890	13.885 .005	13.884 .006	13.878 .012	13.876 .014	13.874 .016	13.873 .017	13.872 .018	13.871 .019	13.870 .020	13.869 .021	13.868 .022	13.867 .023
9	13.460	13.455 .005	13.454 .006	13.448 .012	13.446 .014	13.444 .016	13.443 .017	13.442 .018	13.441 .019	13.440 .020	13.439 .021	13.438 .022	13.437 .023
10	13.160	13.155 .005	13.154 .006	13.148 .012	13.146 .014	13.144 .016	13.143 .017	13.142 .018	13.141 .019	13.140 .020	13.139 .021	13.138 .022	13.137 .023
11	13.460	13.455 .005	13.454 .006	13.448 .012	13.446 .014	13.444 .016	13.443 .017	13.442 .018	13.441 .019	13.440 .020	13.439 .021	13.438 .022	13.437 .023
12	13.320	13.315 .005	13.314 .006	13.308 .012	13.306 .014	13.304 .016	13.303 .017	13.302 .018	13.301 .019	13.300 .020	13.299 .021	13.298 .022	13.297 .023
13	12.970	12.965 .005	12.964 .006	12.958 .012	12.956 .014	12.954 .016	12.953 .017	12.952 .018	12.951 .019	12.950 .020	12.949 .021	12.948 .022	12.947 .023
14	13.450	13.445 .005	13.444 .006	13.438 .012	13.436 .014	13.434 .016	13.433 .017	13.432 .018	13.431 .019	13.430 .020	13.429 .021	13.428 .022	13.427 .023
15	12.970	12.965 .005	12.964 .006	12.958 .012	12.956 .014	12.954 .016	12.953 .017	12.952 .018	12.951 .019	12.950 .020	12.949 .021	12.948 .022	12.947 .023
16	13.320	13.315 .005	13.314 .006	13.308 .012	13.306 .014	13.304 .016	13.303 .017	13.302 .018	13.301 .019	13.300 .020	13.299 .021	13.298 .022	13.297 .023
17	12.970	12.965 .005	12.964 .006	12.958 .012	12.956 .014	12.954 .016	12.953 .017	12.952 .018	12.951 .019	12.950 .020	12.949 .021	12.948 .022	12.947 .023
18	12.960	12.955 .005	12.954 .006	12.948 .012	12.946 .014	12.944 .016	12.943 .017	12.942 .018	12.941 .019	12.940 .020	12.939 .021	12.938 .022	12.937 .023
19	12.900	12.895 .005	12.894 .006	12.888 .012	12.886 .014	12.884 .016	12.883 .017	12.882 .018	12.881 .019	12.880 .020	12.879 .021	12.878 .022	12.877 .023
20	13.450	13.445 .005	13.444 .006	13.438 .012	13.436 .014	13.434 .016	13.433 .017	13.432 .018	13.431 .019	13.430 .020	13.429 .021	13.428 .022	13.427 .023



Amended Design for a Battery Fan Motor from page 43.

Power = 5 watts

Speed = 900 r.p.m. = 15 per sec.

Battery employed = 4 cells Edison Lalande, 300 c. amp. hr type.

E.M.F. = 2·67 volts @ 0·6 volts per cell.

Current = 4 amp.

Res: of battery = 4 × 0·035 Ω = 0·14 Ω

Drop in battery = 0·56 volts.

P.D. at terminals = 2·12 volts

Resistance of leads = 0·03 Ω

P.D. at motor terms = 2·09 volts

E.M.F. of motor = 1·3 volt

Drop in Terms = 70 ~ each limit 420 in all. altered to 36 ~ each limit = 216 turns in all

" = 0·7

Res: of " = 0·175 Ω

" " armature = 0·140 Ω

" " field = 0·07 Ω

Type of armature = Lin - Lindsell.

Flux through limits = 20,000 C.G.S. in each successively.

Cross-section of limb = 1·5 × 1·5 = 2·25 cm²

Effective " " = 2·0

Polar surfaces = 5·5 × 1·5 = 8·25 cm²

Entrefer = 0·020" = 0·05

Air reluctance = 0·1/8·25 = 0·0121

M.M.F. needed = 262 for air say 250.

Exciting power = 200

Turns at load = 50 say 54. altered to 88

Core of field magnet = cast iron.

Internally in core = 5000

Leakage factor = 1·3

Total armature flux = 21,500 at max: in successive intervals

" field " = 42,000

Section of field = 8·4 sq: cms

Diameter " " = 3·3 cms. = 1·33"

Length of mean arm turn = 0·3'

" " arm: winding = 126' altered to say 100

Res: of armature wire = 0·386 Ω @ 20°C

" " " " = 0·097 Ω.

Size of " " = # 17 B.W.G 0·058" s.c.c. 0·065"

Interflange of armature = 1" allowing of 15 turns.

Weight of arm: wire = 1·27 lbs. 18 oz. 12 g.

Diameter of field = 1·3"

Price " " = 4·19' = 0·35'

Length of wire = 20'.

Resistance " = 0·07 Ω

Size " " = # 17 B.W.G. 0·058" c.c.c. 0·065" # 15 B.W.G

Weight = 0·2 lbs. = 10 oz.

Total weight of wire = 1·6 lbs: on motor.

As actually constructed, the resistance of the armature @ 14°C = 0·122 Ω

" " " field = 0·071 Ω.

With an E.M.F of 6·75 volts at terminals and 2 amps. the speed was 1640 r.p.m.

" " " and 0 " " field of 5·75 amps. in field coil

+25

6·50 = give 1640 r.p.m

The clearance is 0·015" = 0·037 cm.

Field altered to 140' of # 15 B.W.G. s.c.c., 9 armature winding reduced to 36 turns on each limb

Measurements of Transformer Losses by Dynamometer.

Constant of #3 upper coil.
Fixed #3 in suspension in series with voltmeter 50.75 volts 1035~ = 0.01404 amp
45° Meson $C_0 = 2.405 \times 10^{-3}$ $c_0/r = 5.01 \times 10^{-5}$

Instrument compensated.
Balance with 3720 ~ in sec. and 19.480~ in pr. ect. Ratio 5.236
Constant of Meson coil #3 from this balance 2.623×10^{-5}

Slattery transformer. Res: after test of primary) 10.308 ~ of secondary) 0.011~

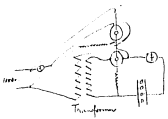
No. of Obs	T	Pr. Amp	Sec. Depn	Sec. Amp	Lamps	Sec. P.D.	Sec. Energy	Ra	Energy in Trans	c^2R	C^2t	$cR+Ct$	Input + Ratio
1	61°	?0.10	–	–	–	53	–	1.0	61	0.1	–		61
2	60.5'	0.25	5°	2.046	3	53	108.5		60.5	0.6	0.2	0.8	59.7
3	61°	0.3	20°	4.092	6	52.8	216		61	0.9	0.7	1.6	59.4
4	61.5'	0.4	74°	7.872	12	52.3	412		61.5	1.7	2.5	4.2	57.3
5	63°	0.6	164°	11.72	18	52.3	613		65	3.7	5.6	9.3	56.7
6	72°	0.8	290°	15.58	25	51.8	807		72	6.6	10.	16.6	55.4
7	85°	1.1	50' c.	21.32	36	51.5	1098		85	12.5	18.6	31.1	53.9
8	119.5'	1.68	105°	30.9	50	49.9	1542		119.5	24.1	39.2	63.3	51.2
9	143.5'	1.95	142°	35.92	66	49.3	1778		143.5	34.2	52.9	92.1	51.4

No compensation after test imperfect and results therefore not reliable.

Stanley) transformer. Res: after test, if pr: = 10.577 sec. = 0.011~
Balance with 3735~ in sec. and 19.480~ in pr. ect. Ratio 5.215
Constant of Meson coil #3 from this balance 2.61×10^{-5}

No. of Obs	T	Pr. Amp.	Sec. Depn	Sec. Amp.	Lamps	Sec. P.D.	Sec. Energy	Ra	Energy in Trans.	c^2R	C^2t	$cR+Ct$	Input + Ratio
1	91°	0.1 ?	–	–	–	52.4	–	1.0	91	0.1	–		90.9
2	91°	0.25	5°	2.046	3	52.4	107	¢	91	0.6	0.1	0.7	90.3
3	92°	0.3	20°	4.092	6	52.3	214		92	0.9	0.2	1.1	90.9
4	93°	0.4	73°	7.818	12	51.6	403		93	1.8	0.7	2.5	90.5
5	95°	0.6	157°	11.46	18	51.5	590		95	3.8	1.4	4.5	90.5
6	99°	0.79	279°	15.28	25	51.0	779		99	6.8	2.6	9.4	89.6
7	110°	0.13	50' c.	21.32	36	50.3	1072		110	13.5	5.0	19.5	90.5
8	127.5	1.55	89°	28.44	50	50.	1422		127.5	27.2	8.9	36.1	91.4
9	155°	2.00	145°	36.20	66	49.6	1800		155	45.3	14.5	59.8	95.2

Compensation after test o.k. Good series



Measurement of Transformer Losses continued. 28th Apr.

Instrument compensated
Balance of #3 upper and #3 lower coils obtained with 3725 ω in lower.
19520 ω in upper circuit. Ratio 5.240
Repeated test of p. 147 with 80 ω light experimental transformer.
Resistance of (primary) coil with leads and ammeter 2.386 ω
" " secondary " alone 0.0398 ω

No.	T	Pr. Disp.	Pr. Amp.	cos.	sin.	Energy Consumption	Sec. Disp.	Sec. Amp.	Lamps	6 Volt	Total Clk. energy	Sec. P.D.	Hysteresis
1	306	-	0·45	0·5	1·00	306	-	-	-		0·5	12·1	305·5
2	305	-	0·7	1·2		305	9°	2·745	6	0·3	1·5	12·1	303·5
3	306	-	1·45	5·0		306	64°	7·32	19	2·1	7·4	12·1	298·9
4	313·0	-	1·95	9·0		310·0	198°	12·88	30	6·6	15·7	11·87	294·3
5	305·5	-	0·45	0·5		305·5	-	-	-	-	0·5	12·1	305·0
6	323·5	46°	2·55	15·5		323·5	346° c.	17·73	45	12·4	27·9	11·78	295·6
7	390	145°	4·53	49·0		390	125°	33·70	89	44·9	93·9	11·40	295·1

The compensation were checked after the test
The variation of the (hysteresis + Eddy) loss with the terminal p.d. was also repeated as follows:—

No. of Obs.	Sec. P.D.	Pr. Amperes	T	Rx	Pr. Watts.	$(P.D.)^2$	y		
1	60·5	0·3	102	1·00	102	709	0·1439		
2	70·2	0·32	130·5		130·5	900	0·145		
3	80·1	0·33	158		158	1110	0·1422		
4	90·2	0·35	197		197	1343	0·1392		
5	100.	0·38	218·5		218·5	1586	0·1378		
6	110·1	0·41	252·5		252·5	1857	0·1360		
7	120	0·41	295		295	2122	0·1390		

Tests of Edison - Lalande Battery for Local Action

140 cells of Phx 150 Amp.hr. E type were set up in two series of twenty cells each on the 21st April. The weights of the zinc plates of which there are two in each cell were observed. The first series were set up in the normal way. The seconds series were set up with zinc plates to which amalgamated copper rods had been attached. These cells were all left on open ct. They contained some 1850 c.c. of NaHO solution of density 1.26 at 18° C.

No. of plate	Weight 21st Apr.	Weight 28th May	Weight 30th June	Weight 31st Aug.			No. of plate	Weight 21st Apr.	Weight 28th May	Weight 30th June	Weight 4th Aug.	Weight Diff. in 4 Aug.
1	177.	176	169.5	163.5			1	150.5	149.5	146.0	141.5	131
1A	169.5	168.2	162.5	157.5			1A	139	138.2	135.0	131.7	124.8
2	173	172	168.5	164			2	143.5	141.7	138.0	80.5	76
2B	173.5	172.2	167.5	162.5			2B	144.5	143	140.0	80.0	74
3	168.5	167.5	163.0	158			3	133.2	132.6	129.0	129.5	121
3C	167.2	165.7	160.5	156			3C	142.	141.	142.5	142.0	132
4	172.	168.7	164.5	160.7			4	127.	126.2	124.0	123	116
4D	186.5	183.7	178.	173.5			4D	137.	136.2	131.5	131.5	125
5	184.7	182.	181.	177			5	141.	141.1	136.	135.	118
5E	174.	173.3	171.5	170			5E	142.5	140.	137.	130.	120
6	169.2	166	167.5	164.5			6	134.5	133.4	132.5	129	120
6F	170.5	169.3	166.5	165.			6F	138.5	137.6	136.5	136	128
7	176	175.5	173.5	170.7			7	142	141.8	140	139	128.5
7G	173.5	173.	171.5	169.2			7G	138.3	137.2	137.	134	125
8	176.7	176.	174.5	172.2			8	144.5	143.5	139.5	×	
8H	171.2	170.2	166.5	160.7			8H	136.8	135.7	133.5		
9	175.7	174.9	172.5	168.			9	137.	136.	132.5	129.5	119
9I	179.2	178.2	176.0	161.2			9I	143.5	142.2	138.	132.0	125
10	176.5	175.7	172.5	166.7			10	146	144	139.	135	126
10J	176.	175.2	172.0	166.5			10J	135	133.8	131.	127.5	121
11	170	169.	166.5	156.5			11	140.7	139.3	136.5	129.5	120
11K	171.5	170.8	168.5	157.2			11K	139.5	138.5	135.0	132.0	124
12	173.5	172.2	169.5	165			12	144.7	143	139.0	134.5	126
12L	173.5	172.5	169.5	164			12L	142	138	131.5	134.0	126
13	170.2	169.5	165.0	161			13	134.7	133.5	119.5	115.5	110
13M	167	166.2	160	157.5			13M	139.2	138.3	137.5	113.	108
14	174.5						14	133	131.3	126.	122.	114
14N	174						14N	135.2	133.7	144.5	139.	128
15	170.7	170.	168.5	163.5			15	128	126.	117	105.5	101
15O	177.6	176.3	174.5	168.5			15O	139.5	137.2	130.	121.0	111
16	167	166.3	159.5	152.0			16	134	132.7	126.	115.0	106
16S	167	166.2	159.5	151.8			16S	132	129.3	125.	117.5	111
17	176	175	168.5	163.5			17	143.7	141.7	136.5	136.	
17T	172.2	170.5	164.5	156.5			17T	129.2	127.5	122.5	122.	
18	169.5	167	164.5	156.5			18	143.5	141.5	137.	137.	
18P	176.5	174.	168.	153.5			18P	142.0	137.2	131.5	×	
19	171.	170.5	161.5	151.			19	145.7	144.5	140.5	136	120
19a	174.2	171.7	170.	163.			19a	143	141.	137.5	132.	125
20	173.	171.2	165.5	160.5			20	139	137.7	130.0	×	
20V	178.7	177.5	171.0	165.0			20V	141.2	140.0	135.5		
Add	1.2 for rod						Add	0.8 for rod				
	6598.5	6564.9	6354.5	6168.1				5588.0	5508.2	5263.0		
Total loss		33.6	210.4	186.4					79.8	245.2		
Loss per plate		0.884	5.54	4.91					1.97	6.13		
Loss per cell		1.768	11.08	9.82					3.94	12.26		
			244.0	430.4						32.5		
			6.42	11.32						8.12		
			12.84	22.64						16.24		

Experiments on the corrosion of lead units.

Six lead plates – Schemetzky's annealed – were weighed on the 20th April and immersed in separate solutions. Their surfaces were (practically) equal to those of all preceding samples.

No. of Plate	Solution	Weight 20th Apr.	Weight 28th Apr.	Weight 29th Apr.	Weight 13th May	
46	P	Carbolic Acid	13.166	13.111 −.055	13.061 −.105	13.005 −.161
47	P	" "	13.330	13.295 −.035	13.223 −.107	13.095 −.235
48	P	Flows rejected water	13.248	13.248	13.248	13.247 −.001
49	P	" " "	13.023	13.023	13.020 −.003	13.020 −.003
50	P	Alcohol methyl	13.284	13.180 −.104	13.053 −.231	12.765 −.519
51	P	Naphthaline in methyl alcohol	13.212	13.130 −.082	13.065 −.147	12.965 −.247

A series was tried with block tin sheet, cut into strips with about the same area of surface as all the other samples.

No. of Plate	Solution	Weight 21st Apr.	Weight 28th Apr.	Weight 29th Apr.	Weight 4th May	Weight 6th May	
50	5% Creosote in H_2O	0.788	0.788	0.789	0.788		
51	5% Wood Tar oil "	0.709	0.711	0.710	0.709		
52	250 c.c. sat. Box Water	0.802	0.802	0.803	0.803		
53	25% H_2SO_4 in H_2O 250 c.c. H_2O sat. $CaSO_4$	0.796	0.775 −.021	0.766 −.030	0.768 −.028	0.768 −.028	0.768
54	5% Acetic acid	0.765	0.738 −.027	0.741 −.024	0.741 −.024	0.744 −.021	
55	1% HNO_3	0.796	0.776 −.020	0.770 −.026	0.769 −.027	0.769 −.027	
56	5% Na_2S	0.838	0.838	0.836 −.002	0.837 −.001	0.837 −.001	0.837
57	5% H_2SO_3	0.818	0.819	0.818	0.815 −.003	0.815 −.003	
58	5% Na HO	0.760	0.760	0.757 −.003	0.758 −.002	0.758 −.002	
59	5% Na_2SO_4	0.747	0.746 −.001	0.746 −.001	0.745 −.002	0.745 −.002	0.746
60	5% Alum	0.846	0.845 −.001	0.845 −.001	0.845 −.001	0.844 −.002	0.844
61	Brunswick Green	0.771	0.770 −.001	0.770 −.001	0.770 −.001	0.770 −.001	
62	5% HCl in H_2O	0.819	0.798 −.021	0.796 −.023	0.726 −.093	0.581 −.238	
63	5% Carbonate of Soda	0.732	0.731 −.001	0.731 −.001	0.731 −.001	0.731 −.001	
64	5% NH_4HO	0.789	0.788 −.001	0.789	0.788 −.001	0.788 −.001	0.788
65	5% NH_4Cl	0.682	0.681 −.001	0.681 −.001	0.679 −.003	0.676 −.006	0.676

Constant of Differential Dynamometer 22nd Apr. 92.

Five measurements were made using the potentiometer to determine the currents, the Constr. of coil + suspension, reduced to independent of the earth's field, and the standard metre strip 0.09945 legal m.

No. of Obs.	T	P.D. Ends on shunt	C	Ratio on Log T	a	C_a	C_a/T	Means	v	v^2	Result
1	114.°	0.347	8.517	1.7214	0.02664	0.2950	2.587×10^{-3}	1.9958^{-3}	0.009	8.1×10^{-5}	
2	267.5°	1.555	15.63	1.707	0.01430	0.5362	2.004 "		0.006	3.6	1.9958
3	270.5°	1.558	15.66	1.710	0.01437	0.5383	1.990 "		0.005	6.4	0.0007
4	271°	1.5665	15.65	1.710	0.01437	0.5379	1.985 "		0.013	16.9	
5	171°	0.9913	9.97	1.711	0.01444	0.3434	2.007 "		0.008	6.4	
										5.51.4	

Efficiency test of 500-volt ½ HP. motor 21st Apr.

No.	Diff. in mm.	Ends of comm.	Effort	Speed	Balance	Moment × 6465	Deliving	Loss in watts
1				–	2100 50 @ – 27			
2				1810	50 @ 3.8			
3				2150	50 @ 5.0			
4				1900	50 @ –8 500 @ 5			
5				1685	50 @ 28.5 500 @ 5			
6				1795	500 @ 10 50 @ 0.0			
7				1710	50 @ 18 500 @ 15			
8				1650	50 @ 20 500 @ 20			
9				1625	50 @ –6 500 @ 5 1000 @ 10			
10			598	1580 263	500 @ 22 1000 @ 10	9.7×10^7	255.4	304

No. of Obs.	Time	Shunt	Current in meter	P.D. on meter terminals	Energy in meter	R. of field	Drop in field	Energy in field	Energy in circuit
				2.556					
1	14.0		1			20 ω			
2	.0	0.859	0.466	483.5	224		9.3 v.		
3	.03	0.893	0.433	547	237		8.7 .		
4	.10	0.117	0.607	546	233		12.2 .		
5	.12	0.139	0.719	542	390		14.4 .		
6	.20	0.159	0.828	547	453		16.6 .		
7	.22	0.192	1.00	547	547		20. .		
8	.32	0.215	1.12	547	613		22.4 .		
9	.35	0.231	1.203	532	640		24.1 .		
10	.37	0.251	1.308	532	696		26.2 .	34.2	662
	.0		0.26	500	130		5.2 .		

N	Mean Depth of ring	Mean breadth of ring	Mean Mid area of cast plate	Mean Thickness in inches	Max B	cub. inches contained	β	$\frac{\beta}{12}$ (=)
1	3.205	$\frac{5.07}{2}$	0.03023	0.0119"	16.020	0.11834	314.8	10570
2	3.201	2.935	0.03138	0.01236"	16.680	0.1637	360.1	11.475
3	3.214		0.03653	0.01438"	15.240	0.248	545.5	14,930
4	3.214		0.03872	0.01524"	17.470	0.270	638.	16,480
5	3.210		0.03116	0.01227"	15.630	0.1637	360.1	11.560
6	3.208		0.03082	0.01213"	16.690	0.1546	340.1	11.030
7	3.202		0.04104	0.01616"	16.440	0.332	726.7	17.900

(57)

Particulars of Rings made up of sheet iron annular disks received from Schenectady on the 25th April

Seven such series of samples were received. They were made up so as to have as nearly as possible the same weight.

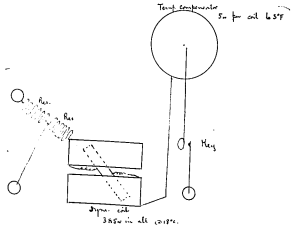
	Maker	No. of Discs	Int. diam.	Ext. diam.	Mean diam.	Mean Ohes	No. of plates	Total mass	Mass per plate	Vol. of plate	Mean thickness	Sp. g.
11	Edg. Williams	30	17.68 / 9.40	22.02 / 8.90	20.135	63.26	106	4010.6	37.84	5114	0.132	7.8
12	Fuller. Bros.	30	"	"	"	"	102	4005	39.27	5113.4	0.130	
13	Standard Iron Co	30	"	"	"	"	88	4021.	45.69	5115.4	0.146	
14	P.H. Lauferman?	28	"	"	"	"	83	4.021	48.44	5115.4	0.146	
15	Connecticut Corrugating Co	30	"	"	"	"	103	4.016	38.99	5114.8	0.137	
16	Charlton	30	"	"	"	"	104	4.010	38.56	5114.0	0.134	
17	Fuller Bros	28	"	"	"	"	78	4.006	51.35	5113.5	0.116	

Tests on the corrosion of lead cable sheathing.

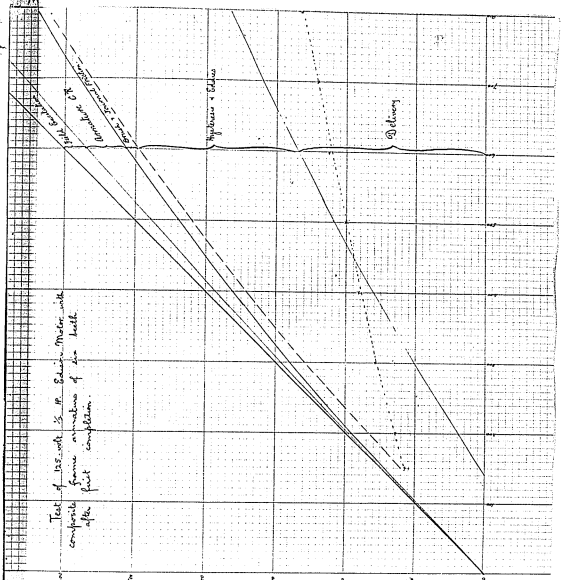
Samples of the standard dimensions were cut from pure chemically lead and immersed in different mixtures with excreta

No. of Test	Solution	Weight 23rd Apr.	Weight 24th Apr.	Weight 7th May	Weight 13th May.
100 P	Small - saturated Naphthalene	15.812	15.813	15.812	15.812
101	Small - solution of Na_2O to excreta	18.516	.013 18.503	.038 18.478	.064 18.432
102	Large - - - - -	17.710	.014 17.696	.026 17.684	.080 17.630
103	Small - - alkaline lime $Ca(HO)_2$ - -	15.909	.004 15.905	.011 15.898	.019 15.890
104	Large - - - - - -	18.138	.006 18.132	.023 18.115	.043 18.095
105	Small - - Na_2O + water - -	17.792	.009 17.783	.019 17.773	.027 17.765
106	Fair treatment with Na_2CO_3 - -	15.787	.009 15.778	.018 15.760	.035 15.725
107	- - - ZnO - -	17.003	17.003	.010 16.993	.023 16.970
108	- - - Baryles - -	16.568	.003 16.565	.017 16.551	.033 16.535
109	- - - Litharge - -	12.833	.025 12.808	.050 12.783	.126 12.707
110	- - - $Na\,Cl$ - -	16.431	.003 16.428	.008 16.423	.019 16.412
111	- - cast iron filing - -	17.405	17.407	.011 17.396	.022 17.352
112	- - H_2O aftermath sewage - -	15.811	.018 15.793	.034 15.787	.031 15.780
113	- - H_2O from #12	13.051	.006 13.045	.025 13.043	.021 13.020
114	Acetone	after 5th 17.296			.022 17.274
115	Orthocresol	17.678			.004 17.674
116	Metacresol	16.413			.050 16.363
117	Metacryfenol	12.676			.026 12.650
118	alpha naphthol dissolve in chloroform	15.883			15.883
119	Beta - - - -	17.486			.018 17.468
120	Rosalic acid - - H_2O	16.692			.013 16.679
121	H_2S water	17.141			.008 17.130
122	Ammonium sulphide $(NH_4)_2S$	18.226			.001 18.225
123	Ammonium sulpho cyanide	17.055			.015 17.040
124	Concentrated solution of NH_4Cl	20.040			.065 20.015

No.	Volts	Ohms	Current	Energy	R. of field	Deflection	Energy in field	R. of armature	Deflection armature	Current armature	Speed of armature rpm	Energy in armature	Energy expended
1	12.5	-	-	-	1+2+4			220 Ω					
2	12.5	0.253	1.239	1.54		1.75	2.2		2.9	122.2	2410	40.1	3.5
3	12.5	0.205	1.89	1.89	1	2.23	3.5		3.58	114.2	2.100	35.0	3.605	5.7
4	12.5	0.368	1.92	2.40		2.69	5.2		4.32	118.0	1917	32.45	3.636	8.3
5	12.5	0.580	3.024	3.78		4.23	12.8		6.80	111.0	1740	29.0	3.930	20.5
6	12.4	0.775	4.041	5.01		5.66	22.8		9.09	109.25	1620	27.0	4.050	36.7
7	12.3	1.01	5.266	6.48		7.37	38.8		11.85	103.8	1530	25.5	4.070	62.3
8	12.2	1.20	6.258	7.64		8.76	54.4		14.08	99.2	1460	24.3	4.08	88.2



Movable coil of aluminium wire ?
Field . . . copper .
Resistance . . German Silver . ?



Test of 120 volt ½ H.P. Edison Motor 25th Apr. 92.

The motor was mounted on the floating cradle, and connected with the ½ H.P. D.+G. The resistance of the armature coil was 2·05 Ω
" " " field " 1·27 "

Volt	Balances	Moment	Gross Moment	Deficiency	Efficiency %	Input Watts	Loss in Brush Friction & Iron	Lamps	Dynamo volts	Dynamo output	Total Loss in Watts	Total Loss
	50 @ 11·5											
5·3	—	—	—	—	0		118·3	—				
9·8	1/200 @ 11·5 / 1/10 @ 11·5	18·25	1125×10⁶	39·11	0·198	99·74	150·74	6 C.P. light			5·81	9·2
11·5	1/200 @ 10·3 / 1/10 @ 11·5	47·55	2·951	176	0·360	0·924	130·5	S.E.S			7·01	13·5
11·7	1/50 @ 11 / 1/200 @ 11·5	83·25	5·133	419	0·39	99·12	195·7	1 λ			11·03	33·3
18·5	1/50 @ 11·5 / 1/100 @ 11·5	131·75	8·122	219	0·437	0·881	221·5	3 λ		2·16	14·75	59·5
21	1/50 @ 11·2 / 1/100 @ 11·5	182·75	11·27	287	0·443	0·884	260·	6 λ		5·0	19·22	101·1
21·0	1/20 @ 11·5+2·5 / 1/200 @ 11·5 / 1/100 @ 11·5	233,50	14·39	348·	0·455	0·813	273	10 λ	37·8	5·2	22·84	113·1

The motor was driven from the D.+G., and without field the frictional moment was approximately 1000 cm.gm. = 0·0165 × 10⁶ ergs from 240 to 16 watts within the range of working speeds.

The effect of exciting the field of the Edison motor, still driven idle in the field, with a current of 6 amperes, was to increase the moment up to 10 000 cm.gms. = 220 to 160 watts within the same range. It diminished slightly with the speed.

When iron wedges were inserted between the teeth of the armature, so as to present a closed magnetic circuit on the exterior, the moment increased to 16,000 cm.gms. when driven by the D.C. with 6 amperes in the field. With brushes lifted 15,000 cm.gms. at

At 1250 r.p.m. 10,000 "

The speed running light on 125 volt was 2220 r.p.m. at 1·7 amp.

Test of Weston Voltmeter 27th April 92. After Repair.

The instrument was examined, repaired, and then tested for its scale error by potentiometer as follows:– Instrument set to its indicated temp

Current		Beyond on Weston	Measured by Potent.	Error
0	+	0·5	0·7	0·7
			1·7	1·7
			1·6	1·6
			0·7	0·7
			0·7	0·7
			0·7	0·7
			0·7	0·7
60		55	55·1	−0·9
			55·5	−0·5
			55·4	−0·6
			54·7	−1·3
			53·6	−2·4
50		50	50·7	0·7
			49·7	−0·3
			49·7	−0·3
40		40	39·7	−0·3
35		35	34·7	−0·3
30		30	29·7	−0·3
25		25	24·7	−0·3
20		20	19·7	−0·3
15		15	14·7	−0·3
10		10	9·7	−0·3

Volts	Measured	Error
120	119·4	−0·6
117	116·7	−0·3
113	113	0.
103·4	107·4	+3·3
105·2	105·5	0·3
99·7	100·4	0·7
95·0	96·0	1·0
90·0	90·9	0·9
83·1	84·3	1·2
80·2	81·5	1·3
75·0	76·3	1·3
70	71·1	1·1
65	66·2	1·2
60	61·6	1·6

Test of ½ H.P. motor with bridges connecting poles. 29th Apr.

Two wrought iron bridges were prepared bridging the polar gaps above and below, tapering to the centre where the breadth remains uniform, but the thickness reduces to about 0·2

124 volts.

1st Test. Field separately excited with approx. 6 amp.

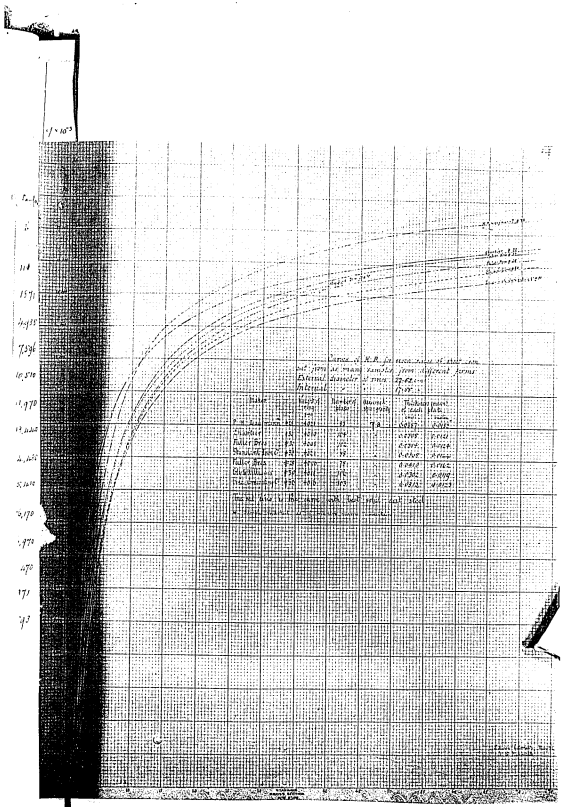
(1)	both bridges on	1783 rpm.	1·43	amperes in armature: 124 volts
(2)	upper off, lower on	1750 "	1·49	" " "
(3)	lower off, upper on	1750 "	1·47	" " "
(4)	both off	1715 "	1·41	" " "

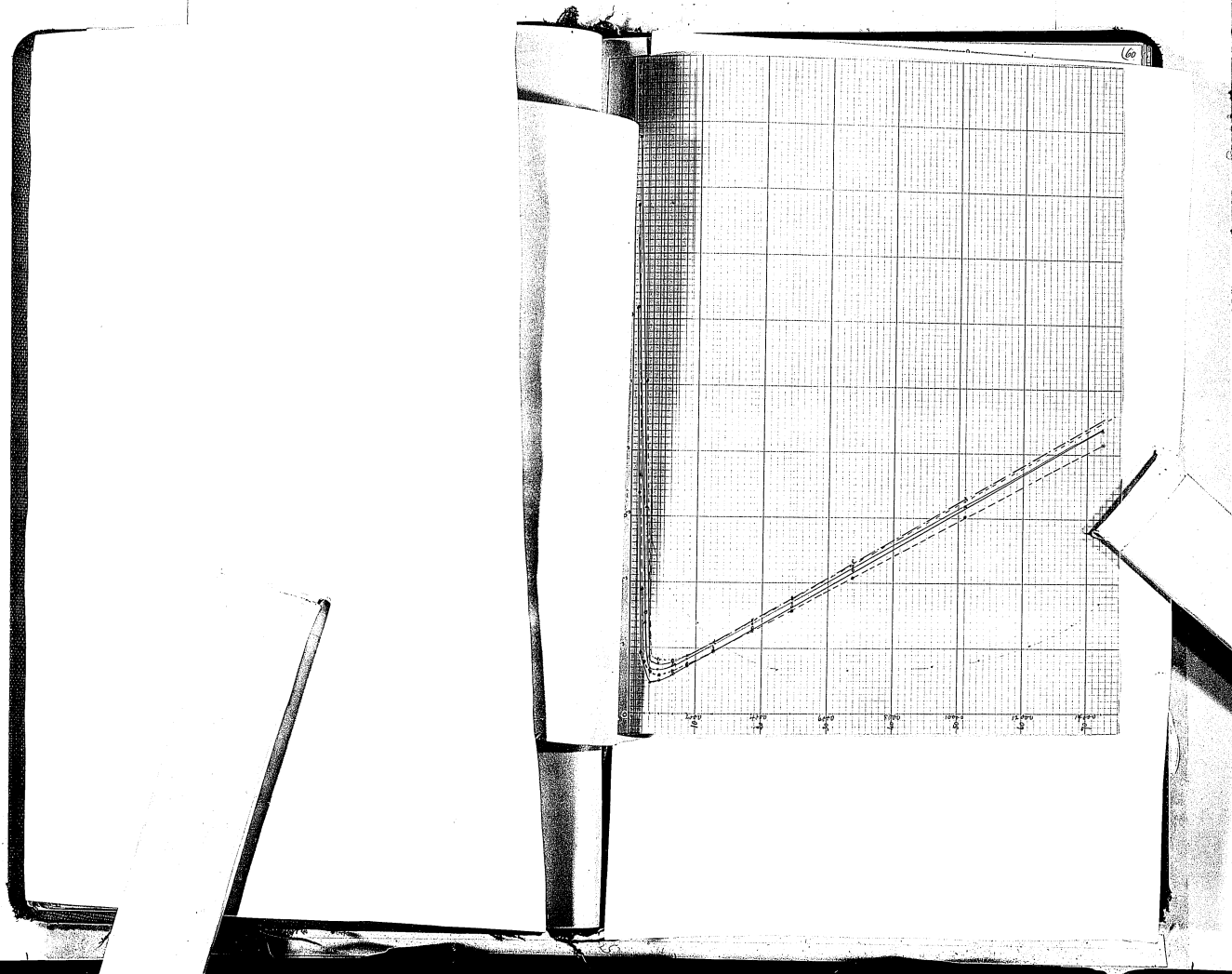
2nd Test Self exciting 124 volts

(1)	both bridges on	2320 rpm.	1·03 amp.	in motor
(2)	upper off, lower on	2310 "	1·06	" "
(3)	lower off, upper on	2340 "	1·06	" "
(4)	both off	2300 "	1·11	" "

Fuller Bros # 30 × Sharlin # 30 × H. P. Comp.

Obsvd	Comp	H	Incl of Grad	ϕ	ξ	ρ	Thous	ϕ	ξ	ρ	Thous	ϕ	ξ
0·032	0·165	0·859	55°25	1·55	118·1	7273	17·5	1122	138·1	6·220	20·5	903	114
0·145	0·143	2·288	50°25	16,650	205·1	1·390	5·3	29,210	357·5	0·793	93	18,210	1871
0·115	0·253	3·087	50°25	36,130	444·52	0·6934	11·5	53,710	660·0	0·4671	171	40,210	4935
0·1675	0·160	4·498	50°25	53,710	661·8	0·6747	17·1	71,780	883·4	0·509·1	228·5	61,890	7596
0·270	1·240	6·716	50°25	74,760	921·2	0·7240	23·8	89,930	11·066	0·6073	286	85,610	10,506
0·331	1·709	8·690	55°25	86,620	1067·5	0·8328	15·1	97,930	12,180	0·7300	172·5	97,500	11,975
0·4375	2·443	12·72	55°25	99,220	12,230	1·040	17·3	107,800	13,270	0·9585	188	109,500	13,444
0·640	3·500	18·53	55°25	110,000	13,580	1·368	191·8	113,300	14,140	1·306	201	118,000	14,48
0·914	4·605	24·30	55°30	116,800	14,390	1·689	203·5	121,000	14,890	1·631	210·8	125,600	15,141
1·260	6·502	33·84	55°30	122,800	15,130	2·227	211	124,800	15,360	2·203	217·5	131,700	16,17
1·90	9·504	51·03	55°30	129,700	15,980	3·194	226	130,000	16,000	3·190	226,5	138,300	16,97
2·609	13·90	74·26	55°30	133,800	16,480	4·391	233	134,900	16,600	4·359	235	142,300	17,47
0·03	0·258	1·344	55°30	3,330	410	3·275	48	3,260	4,012	3·852	47	3,020	37
0·663	0·224	1·167	55°30	10,910	13,44	1·255	171	12,960	1594·1	0·9164	234·5	7,273	89

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Permeability Tests of Six Samples of Drawn received from Schenectady Apr. 30th 1892.

Galvanometer: Galvanometer constant = 50 turns on each secondary. 262 turns on each pr.

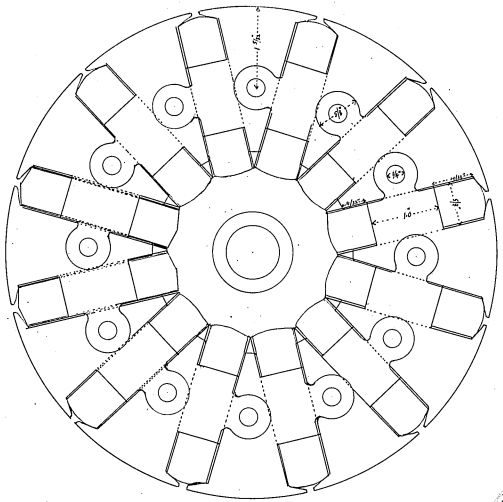
Source of Emf	EMF of battery	Battery	Mean Throw	q	q per div	
Gaulard 216	1.4314	1	137.9	1.4314×10^{-3}	1.038×10^{-5}	
?	× Exp. of Eliminator ÷ 30		× Fullers Accs ÷ 28		× Commercials	Comparison B 30

No.	Throw	q	k	ρ	Throw	q	k	ρ	Throw	q	k	ρ	Throw
1	16.5	794	97.7	8.792	4.5	547	67.4	12.75	10	739	90.8	9.461	13.5
2	48.5	7,352	908.5	3.137	23.5	4,535	561	5.079	114.5	8,109	984	2.896	25.5
3	12.8	26,740	3537.	0.8728	91.5	21,990	2709	1.140	70	25,920	3185	1.9694	82.5
4	197	46,800	5760	0.7809	149	44,390	5453	0.8245	141	45,390	5577	0.8065	144.5
5	272.5	70,210	8640	0.7773	223.5	65,580	8048	0.7950	218.3	68,400	8434	0.7964	218.5
6	170	61,740	10,060	0.8839	142.5	51,450	10030	0.8855	142	81,160	9974	0.8913	141.5
7	191	95,210	11,720	1.085	166.	95,500	11.770	1.081	166.5	93,780	11530	1.102	163.5
8	207	105,800	13,020	1.423	184.5	107,400	13,230	1.401	187.3	104,100	12,830	1.4444	182.
9	218.8	112,100	13,795	1.762	195.5	113,600	13.990	1.737	198	111,500	13,580	1.789	192.5
10	229.5	118,800	14,620	2.311	207	121,600	14,980	2.258	212	117,000	14,370	2.355	204.
11	241	125,100	15,400	3.311	218	127,800	15,740	3.243	222.8	124,800	14,840	3.439	210.5
12	248	130,200	16,020	4.517	227	133,500	16,440	4.401	232.5	127,200	15,630	4.620	221.5
13	43.5	1,660	204	6.589	24	1,210	149	9.020	17.5	1,870	230	5.893	27.
14	114.	3,031	373	4.523	41.5	2,201	271	6.224	34.5	3,733	459	2.676	58.5

Standard Iron Ø

No.	Throw	ρ	q	k	q in g. cal.	H	Amp	Throw
1	0.095	0.0944	1855	228	51.50	0.0944	0.191	32.3
2	0.294	0.3016	5910	726	30.100	0.2925	0.0685	50
3	0.177	0.1702	5570	684	30.100	0.1753	0.0913	176.5
4	0.160	0.1576	7840	963	30.100	0.1486	0.1362	223.5
5	0.152	0.1501	8900	1093	31.100	0.1416	0.1516	265.
6	0.518	0.5113	30,300	3720	59.100	0.4972	0.2473	176.5
7	0.752	0.7424	39,400	4840	55.100	0.7019	0.3578	194.8
8	0.477	0.4708	25,000	3070	55.100	0.4421	0.1941	205.
9	1.414	1.396	74,100	9100	57.100	1.348	0.6177	347.

No.	ρ	q	k	Throw
1	4.395	231	28.3	32.3
2	1.316	1919	235.6	50
3	0.702	6774	831.6	176.5
4	0.748	9340	1146.8	223.5
5	0.854	11,930	1464.8	265.
6	1.133	12,390	1521.4	176.5
7	1.476	12.610	1548.6	194.8
8	1.824	14,670	1800.8	205.
9	4.1491	17,200	2112.1	347.



New design for the 1/2 H.P. Composite Frame Armature

4th May 32.

Number of segments in armature	12
Surface of each segment	$4.5 \times 2.5 = 11.25$ cm²
Cross section of core	$(2.54)^2 = 6.45$ cm²
Contraction	$1/32" = 0.0794$
Full load flux	200,000 useful C.G.S. lines in armature
Useful armature flux density	15,500 $\frac{\text{lines}}{\text{sq. in.}}$
Winding space in each section	$0.5 \times 0.625 \times 1.5 \times 1.388 = 2.38$ sq. cms. 0.369 sq. ins.
Space occupied by insulation	$2.5" \times 0.01" = 0.025$ sq. in.
Space left available	0.344 sq. in.
Number of turns in section	176 in 120 volt motor ; 720 in 500 volt
Cross section of covered wire	$(0.0442")^2$ - - - $(0.021)^2$ - - -
	0.001764 sq. in. - - - 0.000441 sq. in. - - -
Space occupied by wire	0.317 sq. in. 0.317 sq. in.
Local reluctance to one spool	$\frac{0.0794}{5.625} \times 2 = 0.0282$ +
Spool MMF	$1.257 \times 530 = 662$
Local flux	23500
" B in arm. + pole face	4,173
Main flux density in pole face	5,330.

Tests on the corrosion of lead sheathings contd.

Plain Schenectady lead.

No. of plate	Solution	Weight 2nd May	Weight 6th May.	Weight May 9th	Weight 20th May
125	Aniline oil	16.628	16.617		16.603 / 16.617
126	Pyradine	16.1425	16.1425		16.626
127	Tap water	16.601	16.604		16.604
128	Beech wood tar Creosote.	16.574 / May 4th	16.546		16.576 / 16.581
129	Pure coal tar creosote	16.500		16.1446 / -054	16.378 / .122
130	" - - - -	16.720		16.666 / .054	16.593 / .127
131	- - - - -	16.670		16.648 / .022	16.537 / .131
132	Creosote treated with strong caustic	16.480		16.4714 / .009	16.348 / .119
133	" - - - - -	16.705		16.732 / .013	16.717 / .029
134	- - - - - -	16.745		16.738 / .007	16.723 / .015

Test made of efficacy of Edison Transformer Patent.

May 6th

A commutator was made of the type represented in this patent. There were two low pressure segment rings, two high pressure segment and six battery segments, mating in all 8 brushes and 3 batteries. 21 small storage cells were made up each of two lead plates 7×10 separated by ⅛". They were "formed" by charging and discharging a suitable number of times. The commutator made about 1750 rpm. It charged the three batteries of 21 cells in all for ⅙ of the whole time with a mean current of 2.5 amps. at 125 volts pressure, and then discharged the cells in 3 rows of 7 during ⅔ of the whole time at a mean current of 5 amps. and 12.5 volts = 62.5 watts.

If the secondary circuit be interrupted, the current in the primary falls to 2.0 amps showing that the supply of 0.5 amp over and above this amount goes almost wholly into the secondary ckt.

Experiments on treating creosote to render it inoperative on lead

No of Plate	Solution	Weight 10th May	May 14th	May 18th	May 21st
135	Creosote treated with $Cu\,Cl_2$	16.740	16.737 / -003	16.726 / .011	16.723 / .014
136	" - - $Na_2\,SO_4$	16.740	16.740 / .000	16.735 / .005	16.733 / .007
137	- - - $Na\,NO_3$ and	16.595	16.585 / .010	16.569 / .026	16.559 / .036
138	- - - $Na\,SiO_3$	16.720	16.690 / .030	16.684 / .036	16.680 / .040
139	- - - $Mg\,SO_4$	16.840	16.825 / .015	16.810 / .030	16.804 / .036
140	- - 10% H_2SO_4 in H0	16.645	16.647 / -002	16.645 / .000	16.644 / .001
141	- - - $NH_4\,SO_4$	16.690	16.670 / .020	16.665 / .025	16.659 / .031
142	- - - $Na\,CO_3$	16.700	16.675 / .025	16.672 / .028	16.668 / .032
143	- - - Rosin	16.760	16.755 / .005	16.743 / .017	16.738 / .022
144	- - - $Fe\,O$.	16.665	16.660 / .005	16.648 / .017	16.640 / .025
145	- - - $Fe\,SO_4$	16.690	16.685 / .005	16.672 / .018	16.662 / .028
146	- - - MnO_2	16.000	15.975 / .025	15.945 / .055	15.932 / .068
147	- - - $Sn\,Cl_2$	16.032	16.0145 / .018	16.004 / .028	16.007 / .025

The eddy current activity per sq. cm. of a thin iron sheet (thickness $2h$) of mass m submitted to a simple harmonic force $H \cos pt$ is

$$\frac{\rho m H^2}{16\pi^2} \cdot \frac{\sinh 2mh - \sin 2mh}{\cosh 2mh + \cos 2mh} \quad ; \quad \text{where } m = \sqrt{\frac{2\pi\mu p}{\rho}} = 2\pi\sqrt{\frac{\mu}{\rho p}}$$

In these experiments $p = 890$. ρ = say $1.1 \times 10^{+}$ $\quad m = \sqrt{\frac{6.283 \times 2\pi 0890 \times 10^{6}}{1.1 \times 10^{2}}} = \sqrt{2.051 \times}$

μ = . 2×10^{3} $\quad = 31.89$ say 32.

$\frac{\rho m}{16\pi^2} = \frac{1.10 \times 3.2 \times 10^{5}}{160 \times 10^{2}} = 2.2 \times$

For Ring #1 p. 57.	$2h = 0.0302$	$2mh = 0.9664$	$\frac{1.12 - 0.819}{1.447 + 0.574} = \frac{0.301}{2.021} = 0.$
2 . . .	$= 0.0314$	$= 1.0045$	$\frac{1.152 - 0.841}{1.543 + 0.540} = \frac{0.341}{2.083} = 0.$
3 . . .	$= 0.0365$	$= 1.168$	$\frac{1.4585 - 0.9285}{1.766 + 0.390} = \frac{0.5350}{2.156} = 0.$
4 . . .	$= 0.0397$	$= 1.269$	$\frac{1.583 - 0.946}{1.872 + 0.325} = \frac{0.637}{2.197} = 0.$
5 . . .	$= 0.0312$	same as #2	$= 0.$
6 . . .	$= 0.0306$	mean of 1 + 2.	$= 0.$
7 . . .	$= 0.04410$	$= 1.312$	$\frac{1.715 - 0.967}{1.982 + 0.255} = \frac{0.751}{2.246} = 0.$

for an exceeding thin disk

$$W = \frac{4}{3\rho} H^2 \mu^2 p^2 h^2$$

$$= \frac{4 \times 4 \times 10^{6} \times 7.921 \times 10^{6}}{3 \cdot 3 \times 10^{2}} h^2 H^2$$

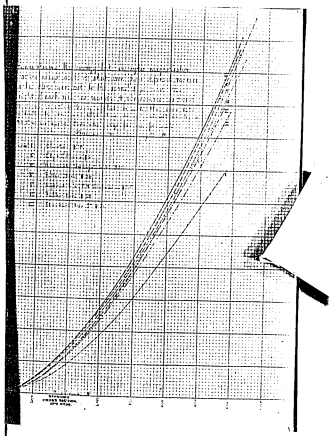
$$= 3.841 \times 10^{8} h^2 H^2$$

For #1 $h = 0.0151$ $\quad h^2 = 3.443 \times 10^{-4}$

$$W = 3.841 \times 3.443 \times 10^{+4} H^2$$

$$= 1.322 \times 10^{3} H^2$$

$$= 43.780\ H^2 \text{ per e.c. cyp.} \div 8 = 5,473\ H^2$$



Tests of seven rings from Schenectady Steel Iron.

262 turns on each ring. Tested with the N.E. end of the single Symmonds 16th x 1/4/17

Thurston #20

n	R	Rdt	P.D. in ring	amp	ck.	EmF	B_{max}	cR	Watts in kgs. cells	Watts per kg. all but kgs. cells	
										12,700	
22'	4440	1·25	13	0·25?	-	13	970	-	1·25	1747	
5		4·26	25	0·1	-	25	1866	-	4·26	585·3	
16.		9·09	40·4	0·2	-	40·4	3016	0·01	9·09	1248	
27		18·34	54·5	0·3	0·1	54·7	4083	0·03	18·34	2108	
40		22·73	71·3	0·35	0·1	71·2	5315	0·04	22·69	3118	
56		31·52	87.	0·40	0·1	86·9	6486	0·05	31·77	4365	
70·5		40·86	100.	0·46	0·1	99·9	7457	0·06	40·0	5498	
89'		50·87	115.	0·53	0·2	114·8	8569	0·08?	50·69	6937	
109·5'		62·21	130·3	0·62	0·2	130.	9703	0·11	62·1	8532	
137·0'		79·54	151.	0·75	0·2	150·8	11,260	0·17	77·67	10,670	
160·5		91·20	169·3	0·93	0·3	169.	12,620	0·26	90·94	12,495	
197·5		105·2	190·3	1·39	1·4	189·1	14,180	0·87	107·63	14,790	
214·5		121·9	213·1	3·22	1·0	212·1	15,830	3·05	118·82	16,330	
					H.P. Cauffmann	25				12,700	
10·5'	2050	3·09	17·25	0·2	0·07	17·18	1279.	0·01	3·08	422.	
43·5'	2160	13·31	39·85	0·35	0·15	39·7	2956	0·04	13·27	1818	
66'	2600	24·31	59·5	0·44	0·15	59·35	4420	0·07	24·24	3321	
109'	2490	38·45	80·8	0·54	0·20	80·6	6000	0·10	38·35	5255	
171'	2220	53·79	100·7	0·62	0·28	100·5	7482	0·13	53·66	7352	
122'	4120	71·22	119·4	0·72	0·24	119.	8859	0·18	71·04	9734	
151'	4250	83·26	140·2	0·81	0·2	140·2	10430	0·22	83·04	11,380	
183·5	4090	106·4	157·2	0·96	0·3	156·9	11,830	0·31	106·09	14,540	
229·5	4150	134·9	175·9	1·20	0·4	175·5	13,060	0·49	134·41	18,420	
301'	4030	171·9	204·7	1·95	0·7	204	15,190	1·24	170·61	23,372	
					Julius Bros	#29				13,720	
10'	2880	3·98	20·7	0·30	0·1	20·6	1539	0·03	3·95	543.	
39·5	2310	12·93	40·6	0·38	0·1	40·5	3027	0·05	12·88	1771	
89·5	2070	26·25	58·6	0·44	0·1	58·5	4372	0·07	26·18	3600	
128	2160	39·2	81·2	0·53	0·2	81.	6053	0·1	39·1	5376	
90·5	4250	54·5	99·8	0·68	0·2	99·6	7446	0·2	54·3	7468	
116·	4400	72·3	118·4	0·74	0·2	118·26	8826	0·2	72·1	9914	
120·5	4110	70·15	119·4	0·73	0·3	119·3	8900	0·2	69·95	9618	
144·5	4330	91·73	140.	0·87	0·3	139·7	10,440	0·3	91·43	12570	
180'	4560	116·3	157·6	1·08	0·4	157·2	11,750	0·4	115·9	15940	
264·5	4050	164·6	191.	1·84	0·5	190·5	14,230	1·2	153·4	21,090	
					Sy. Williams #30					14,180	
9·5'	2310	3·11	18·7	0·3	0·1	18·6	1388	0·03	3·08	423·5	
30'	2660	11·31	40·3	0·38	0·1	40·2	3,000	0·04	11·27	1550	
69.	2230	21·80	59·7	0·47	0·2	59·5	44441	0·07	21·73	2988	
98.	2510	34·93	81·1	0·57	0·2	80·9	6018	0·11	34·74	4777	
140.	2550	50·54	101·5	0·70	0·2	101·3	7561	0·16	50·42	6934	
103·5	4270	65·64	118·7	0·80	0·20	118·4	8337	0·22	65·42	8996	
144·5	4130	84·57	140·	1·0	0·3	139·7	10,430	0·34	84·23	11,583	
180	4110	104·8	161·	1·33	0·4	160·6	11,990	0·6	104·2	14,330	
214'	4080	123·7	184·5	2·02	0·7	183·8	13720	1·4	122·3	16,820	

Tests of seven rings from Schenectady sheet. now.

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Mark		r	R	Rat	P.D. at ring	amp.	ch	Emf	B max	ch	Watts per kgm cold	Temp for per watt Hot Cold	
#30	1	10°	2630	3·73	20·6	0·3	0·1	20·5	1528	0·03	3·70	74·200 507·6	
Schenectady #30	2	25·5	2870	11·54	40·7	0·38	0·1	40·6	302·6	0·05	11·54	1583.	
	3	65°	2360	21·73	59·5	0·44	0·2	59·3	4420	0·08	21·65	2970.	
	4	105°	2450	36·45	81·8	0·60	0·2	81·6	6020	0·12	36·33	4984.	
	5	152	2375	51·11	99·9	0·70	0·2	99·7	7430	0·16	50·95	6990.	
	6	113	4330	69·33	119·4	0·81	0·3	119·1	8876	0·22	69·11	9481	
	7	144	4310	89·92	138·4	0·97	0·3	138·1	10,290	0·32	87·6	12,020	
	8	183·5	4340	112·8	160·4	1·35	0·4	160.	11,920	0·6	112·2	15,390	
	9	230·5	4110	131·2	179·8	1·90	0·6	179·2	13,360	1·2	130·0	17,830	
	10												
Schenectady #29	1	12·5	2370	4·20	20·7	0·3	0·1	20·6	1534	0·03	4·17	72,900 571·3	
	2	39·5	2240	12·58	40·5	0·40	0·1	40·4	3008	0·05	12·48	1710.	
	3	70·5	2440	24·37	59·5	0·5	0·2	59·3	4415	0·08	24·29	3328.	
	4	112·5	2370	38·44	79·8	0·6	0·2	79·6	5927	0·12	38·32	5251.	
	5	168·5	2360	56.33	99·9	0·72	0·3	99·6	7416	0·16	56·17	7696.	
	6	121.	4330	74·23	118·5	0·8	0·3	118·2	8801	0·22	74·01	10,140	
	7	151·5	4450	95·52	140·4	0·96	0·3	140·1	10430	0·32	95·2	13,040	
	8	186·5	4420	116·8	158·4	1·14	0·4	158·	11,360	0·4	116·4	15,950	
	9	240	4230	143·8	180·2	1·5	0·5	179·7	13,380	0·8	143·0	19,590	
	10	274	4200	163	193·7	1·89	0·6	193·1	14,380	1·2	161·8	22,170	
Fuller Burr #32	1	8·5	2760	3·08	18·2	0·3	0·1	18·1	1353	0·03	3·05	74,700 420.	
	2	33.	2520	11·79	40·4	0·36	0·1	40·3	3012	0·04	11·75	1616.	
	3	64.	2310	22·58	60.	0·45	0·2	59·8	4469	0·07	22·51	3097	
	4	102.	2570	35·15	82·6	0·52	0·2	82·4	6158	0·08	35·07	4825	
	5	84	4180	44·75	99·2	0·60	0·2	99	7398	0·12	44·63	6828	
	6	110·5	4320	67.63	118·8	0·75	0·3	118·5	8856	0·19	67.44	9279	
	7	150	4110	87·34	140.	0·89	0·3	139·7	10,440	0·27	87·07	11,980	
	8	185·5	4160	109·3	159·6	1·10	0·4	159·2	11,900	0·4	108·9	14,980	
	9	227.	4050	130·2	177·5	1·47	0·5	177·0	13,230	0·7	129·5	17,820	
	10	260.	4150	152·9	196·3	2·05	0·7	195·6	14,620	1·4	151·5	20,840	

Test of three samples of Western Electric Lead.

	Solution	Weight May 5th	Weight May 20th			
150	Conc. cuvette	15.807	15.795 -012			
151	" "	16.072	16.068 -004			
152	" "	15.467	16.461 -006			

No.	Type of cell	E Mean	r Mean	E²/r	List price	E²/per.	Amp. hrs.
1	Mason Wood	1·9	0·09	3·61	40·1		170
2	Chromic acid	1·8	0·15	3·214	18·0		30
3	Fuller.	1·8	0·40	3·24	8·1	1·00	8·1 68
4	W.U. Easton	1·8	0·4	3·24	8·1	1·25	6·48 5
5	Gravity	1·0	0·5	1·0	2·0	0·90	2·22
6	Leclanché	1·5	0·5	2·25	4·5	1·00	4·5 –
7	Partz Nitric cell	1·83	0·51	3·35	6·6		63·5
8	Hussey Eclipse	1·4	0·8	1·96	2·45	2·50	45

Test of Edison-Lalande cells. May 92.

(65)

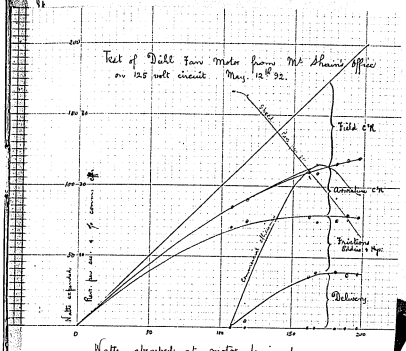
No.	Cell	Amp. Hrs.	Mean Emf	Mean r	E²/r	List price	E²/per	Size of copper ends	Zincs	Weight of Caustic Soda per one charge
1	A	15	0·667	0·508	0·589	0·75	1·085	1¼ 2"×3"	1	
2	B	15	("	0·500	0·889					
3	C	50	0· "	0·180	2·470	1·15	2·148		1	
4	E	150	"	0·070	6·348	1·85	3·431	1¼ 3"×4"	2	1 lbs.
5	G	300	"	0·048	10·383	2·50	~~4·365~~ 4·13	1¼ 4"×4"	2	2 lbs.
6	K	"	"	0·025	~~17·28~~ 17·78	2·50	~~7·11~~ 7·11	2¼ 3"×4"	2	2 lbs.
7	M	600	"	0·013	34·18	6·75	5·063	4¼ 4"×4"	3	4 lbs.
8	F	150		0·020	22·22	-	-	4¼ 3"×4"	3	
9	P	600	"	0·020	22·22	4·85	4·581	2¼ 4"×8"	2	4 lbs.
10	T	900	"	0·018	24·70	6·25	3·951	2¼ 4×4"	2	6 lbs.
11	N	50	"	0·100	24·70	-	-		1	
12	L	300	"	0·017	26·15	-	-	4¼ 3"×4"	3	2 lbs.
13	D	40	1·333 0·667	1·0 0·190	1·778 2·339	2·50	0·711		2	16 oz.
14	K								1	

Measurements made on the resistance of a Battery of F cell. 10th May.

	Diagram	E	PD.	Amp.	C.	r
Plates removed from the square F cell and placed in the round K jar		0·669	0·565	0·104	5·65	0·018 ω
One outside zinc removed altogether		0·672	0·540	0·132	5·40	0·024 ω
Both outside zincs removed		0·671	0·482	0·189	4·82	0·039 ω
Center zinc removed and one outside zinc replaced		0·670	0·392	0·278	3·92	0·071 ω
Other outside zinc replaced, center sheet removed		0·670	0·442	0·226	4·42	0·051 ω
Copper electrode changed		0·670	0·436	0·235	4·36	0·053 ω
All three plates replaced		0·672	0·562	0·110	5·62	0·0194
Plates replaced in square F jar		0·672	0·535	0·137	5·35	0·0256

No. of Obs.	P.D. at Terminals	Brush	Amps thro motor	Energy in motor	Res. of field	Drop in field	Energy in field	Energy in arm.	Res. of arm.	Drop in arm.
			amp.	watts		volts	watts	watts	ohms	volts
1	125	0·165	0·860	107·5	31 ohms	26·66	22·9	84·6	19 ohms	16·3
2	"	0·180	0·9385	117·3		29·1	27·3	90·0		17·8
3	"	0·250	1·303	162·9		40·4	52·6	110·3		24·9
4	"	0·256	1·335	166·9		41·4	58·2	108·7		25·4
5	"	0·279	1·455	181·9		45·1	65·6	116·3		27·6
6	"	0·289	1·507	188·4		46·7	70·4	118·0		28·6
7	"	0·302	1·574	196·8		48·8	76·8	120·0		29·9

When driving the fan at regular 125 volt speed — 1470 rpm. the motor takes 1·20 amp or 150 watts.



Test of a Dühl 115 volt fan motor 12th May 92.

This motor was borrowed for test from Mr Sharin's office in New York. Its weight is 21 lbs. 5 oz. with fan — no guard.
It drives a 6 bladed fan, like the C.W., but with flat blades. Diam: 12".
The armature revolves outside the field. Diam: of arm: 6¼" ext.
Wires: of armature 15·5 – 18·5 ω. Field 29 ω. Total 44·5 – 47·5 ω. @ 18°C.
Running at 125 volts, with fan, it makes 1470 rpm, and takes 1·2 amp.
or 150 watts. The motor was mounted in the float and coupled to the 1/6 H.P. Perret. Diam: of armature 6¾" on the outside.

Eff in %	Counter EMF volts	Effort	Speed. rpm.	Brake Balance	Moment	Gross Moment	Delivery	Frictional Effic'y & friction	Com-eff.	Cond.
	82	70·7	2000	13·5	50 –	–				Running light
	78·5	74·3	1960	32·7	50 ⊙ 4	200	1233 × 10⁴	1103	70·27	0·032	Coupled to float
	59·8	78·0	1280	21·3	10 @ 35 / 100 @ 10	2750	1695 × 10⁴	36·15	21·8	0·227	S. E. float P.
9	58·2	74·8	1210	20·7	50 @ 10·57 / 100 @ 10	3025	1865 –	38·6	36·2	0·231	Load on float
2	52·3	76·1	1100	18·3	50 @ 20 / 100 @ 20	3500	2·158 –	39·55	36·5	0·218	"
2	49·7	74·9	910	15·2	50 @ 27 / 100 @ 25·3	3950	2·435 –	37·0	37·9	0·196	"
·6	46·3	73·0	800	13·5	50 @ 23 / 100 @ 10 / 100 @ 25	4650	2·866 –	38·2	34·8	0·194	"

Resistance of motor after test 50·05 – warm.
Motor packed and returned to Mr Sharin.

Test of Edison Model Motors.

Four Edison model motors were shipped to Lynn, Mass. on the 12th & 16th May, addressed to Mr E. Rice. The tests were as follows

Model	Wound for	R.P.M. of motor	Brush	Amp.	Watts	Speed	Work
1/12 H.P.	125 volts	125		0·35	44	1330	Driving 9" fan
"	500 "	~~500~~ 495		0·09	45	1725	" " "
1/6 "	125 "	125		0·5	62·5	2120	Lifting 100 lbs
"	500 "	495		0·15	73	1385	Driving 12" fan

Experiments on rendering Creosote inactive on lead

No.	Treatment	Weight on Date May 16th	Date May 18th
1168	Creosote heated with PbO	16·360	16·355 ·005
1169	" " "	16·178	16·172 ·006
1170	" " Na_2SO_4	16·128	16·128
1171	" " "	16·121	16·121
1172	" " H_2SO_4	15·860	15·861
1173	" " "	15·883	15·884
1174	" " NH_4OH	16·599	16·601 ·134

Motor driving 11½" fans. 6 blades

Slow. speed 1330 r.p.m. Blank 0.106 Amp. 0.0547 120 volts 6.5 watts
High " 1850 " " 0.172 " 0.888 118.5 " = 105.2 watts

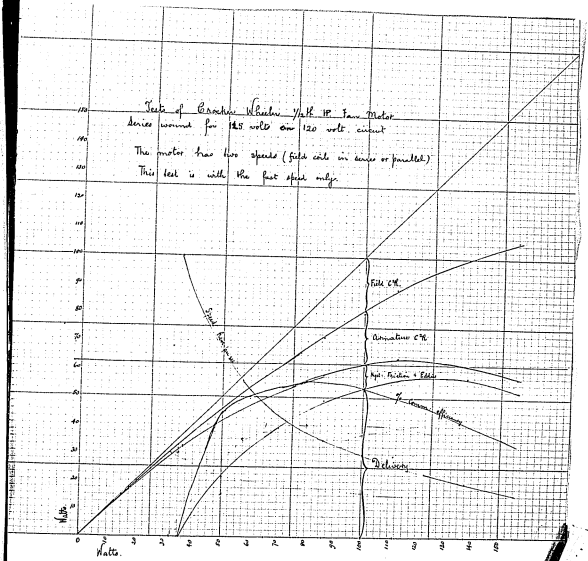
Motor fitted with Edison General 10½ 9" fan with 6 blades

Slow. speed 2170 r.p.m. Blank 0.060 Amp. 0.3096 118 volts = 36.5 watts
High " 3140 " " 0.100 " 0.516 120 " = 61.9.

No. of Obs.	P.D. at Motor terms.	Obsvtn.	Amp.	Energy in Motor watts	Resr. of field ohms	Drop in field volts	P.D. at armt. volts	Energy in field watts	Energy in armature watts	Resr. of armt. ohms	Drop in armt. volts
1	12.6	0.055	0.287	36.2	25	7.2	118.8	2.1	34.1	25	7.2
2	12.6	0.032	0.167	21.0	100	16.7	109.3	2.8	18.2	"	4.2
3	12.5	0.05	0.261	32.6	"	26.1	98.9	6.8	25.8	"	6.5
4	12.5	0.103	0.537	67.1	"	53.7	71.3	28.8	38.3	"	13.4
5	12.5	0.112	0.584	73.0	"	58.4	67.6	34.1	38.9	"	14.6
6	123	0.05	0.261	32.1	100	26.1	96.9	6.8	25.3		
7	123	0.060	0.313	38.5	"	31.3	91.7	9.3	28.7	"	6.5
8	122	0.072	0.375	45.8	85	31.8	90.2	11.2	34.6	"	5.3
9	120.4	0.088	0.459	55.3	86	39.5	112.6	3.5	42.3	-	2.4
10	120.4	0.110	0.573	69.0	27	15.5	104.9	8.9	60.1	27	15.5
11	119.4	0.136	0.709	84.7	28	19.9	99.5	14.1	70.6	28	19.9
12	120.0	0.157	0.819	98.3	29	23.8	96.2	19.5	78.8	29	23.8
13	119.0	0.170	0.886	105.4	-	25.7	93.3	22.8	82.6	-	25.7
	118.8	0.196	0.995	118.7		28.7	91.1	28.5	90.2		25.7

Repetition of Test of ½ H.P. Motor complete assist

No. of Obs.	P.D. at Motor terms	Obsvtn	Amp	Energy in Motor	Resr. of field ohms	Drop in field	P.D. at armature	Energy in field	Energy in armt.	Resr. of armt.	Drop in armt.
1	122.4	0.055	0.284	34.76	99.6	28.3	94.1	8.04	26.72	25.0	7.1
2	121.4	0.061	0.315	38.24	103.6	32.6	88.8	10.27	27.97	26	8.19
3	121.4	0.080	0.413	50.14	106	43.8	77.6	18.09	32.05	26.3	10.9
4	121.4	0.092	0.475	57.66	108.1	51.3	70.1	24.37	33.29	26.5	12.6
5	120.4	0.106	0.547	65.86	26.7	14.6	105.8	7.99	57.87	26.4	14.4
6	118.5	0.142	0.733	86.9	27.0	19.8	98.7	14.51	72.4	26.7	19.6
7	117.5	0.165	0.851	100.0	27.5	23.4	94.1	19.92	80.1	27.1	23.1
8	121.4	0.178	0.918	111.5	27.9	25.6	95.8	23.50	88.0	28.2	25.9
9	119.4	0.223	1.151	137.4	28.4	32.7	86.7	37.63	99.8	28.7	33.
10	118.5	0.254	1.311	155.3	28.4	37.2	81.3	48.77	106.5	28.7	37.6
11											
12											
13											


Tests of Crocker Wheeler ½ H.P. Fan Motor
Series wound for 125 volts on 120 volt current
This motor has two speeds (field coils in series or parallel)
This test is with the fast speed only.
Field C.W.
Armature C.W.
Appl. Friction & Eddy
Mechanical efficiency
Delivery
Watts
Watts.

Test of 1/12 H.P. Crocker-Wheeler Fan Motor

This motor was received from the Edison General Electric Co. 1 of New-York store rooms. It is marked Type T # 3580 speed 1700 110 volts 0.15 amp.
Its weight is 19 ½ lbs. without fan or guard.
The resistances of the machine are:- One field magnet 47.2 Ω @ 15°C
The other " " 52 "
In series 99.2 "
In parallel 24.7 "
Armature 2.5 "
Machine at slow speed 125 Ω. mmm 142 Ω
" " fast " 50 Ω. 58 "

E.M.F. in volts	Energy in watts	Effort	Speed r.p.m.	Speed r.p.s.	Balance	Moment	6165 × Moment	Delivery	Friction Kupfer's Effect	Commun. eff.	Load
111.6	22.1	32.	6000	100	–	–			32.	–	Light Test
105.1	0.7	17.5	4600	76.7	–	–			17.5	–	" Slow
92.4	1.7	24.1	3880	64.6	50 ⊙ 65	525	2.093 X10⁶	12.95	11.1	0.397	Slow-after Test
87.9	7.2	31.1	3400	23.3	50 ⊙ 31.3	1565	9.647 "	22.5	8.6	0.335	Slow S.E.F.
83.0	1.5	30.4	1080	18.0	50 ⊙ 93	2150	13.25 "	23.9	6.5	0.327	Slow 1 L.F.
80.5 / 80.4	1.7	23.4 / 28.4	3200	53.3	50 ⊙ 18.5	525	3236 "	17.25	76.35	0.539	Fast. S.E.F.
129.9	2.5	26.3 / 33.5	2165	36.1	50 ⊙ 14	700	4315 "	15.6	12.7 / 17.6	0.405	" "
110.2	3.5	38.8	3760	62.6	50 ⊙ 20	1000	6165 "	38.6	0.2		Slow "
96.6	5.5	44.3	2880	48.0	50 ⊙ 25	1250	7706 "	37.0	7.3	0.669	" "
99.4	8.9	51.2	2600	43.3	50 ⊙ 32	1600	9862 "	42.7	8.5	0.619	Fast "
79.6	14.1	56.5	2040	34.0	50 ⊙ 45 ins ⊙ 20	2250	13871 "	47.2	9.3	0.557	" "
72.4	19.5	59.3	1740	29.0	50 ⊙ 055 ins ⊙ 25	2775	17.11 "	49.6	9.7	0.505	" "
67.6	22.8	59.8	1600	26.6	100 26 / 50 25	3300	20.34 "	54.2	5.6	0.574	" "
62.4	28.5	61.7	1420	23.8	100 31 / 50 31	3850	23.58 "	53.6	6.1	0.452	" "

In the 1/6 H.P. motor.

E.M.F. in volts	Energy in watts	Effort	Speed		Balance	Moment	6165 × Moment	Delivery watts	Friction Kupfer's Effect	Commun. eff.	Load
57.1	2.02	24.7	2655	44.3	50 ⊙ 16	550	3.391 X10⁶	15.02	9.7	0.432	S.E.F.
50.6	2.53	25.39	2160	36.0	50 ⊙ 23	900	5.550 "	19.93	5.4	0.523	1 L.F.
46.7	4.50	27.55	1744	29.1	50 ⊙ 29	1150	7.090 "	20.63	6.9	0.411	2 " 1 Arm
57.5	5.98	27.31	1339	22.3	50 ⊙ 37	1650	10.17 "	22.68	4.6	0.393	1 1
91.4	7.88	58.0	2925	46.8	50 ⊙ 20	1250	7.706 "	36.07	13.9	0.543	2 0
79.1	14.4	58.6	2081	34.7	100 ⊙ 20 / 50 ⊙ 17	2300	14.18 "	49.20	8.8	0.566	1 1
71.0	19.7	60.4	1766	29.4	100 ⊙ 24 / 50 ⊙ 23	2900	17.88 "	52.56	7.4	0.526	1 2
70.0	23.8	64.2	1643	27.4	100 ⊙ 27 / 50 ⊙ 27	3350	20.66 "	56.60	7.6	0.506	1 2
86.4	38.	61.8	1181	19.7	200 ⊙ 20 / 100 ⊙ 19	4700	28.98 "	57.09	4.7	0.416	2 3
80.9	99.3	57.2	928	15.5	200 ⊙ 31 / 100 ⊙ 31	5450	33.61 "	52.09	5.1	0.335	3 4

Experiments on induction between wires in cables

A series of experiments was carried out on the 25th May in the presence of Messrs Adams, of the E.G.B., Dr Fuller, & Mr Taylor of the Puna. Co. Altoona, and of which the following are the particulars.

Two lead-covered cables were laid on the palings of the Laboratory and Phonograph Works, so as to enclose all the Buildings in one complete circle, commencing and terminating at the Galvanometer Room.

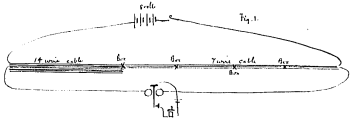
These were lead-covered cables. The first extended from the Galvanometer Room for 966 feet. This was a 7-pair cable of #18 B+S. guage (14 wire in all) The first 470' was saturated with paraffine, and the remaining 496' was unsaturated core (paper). The second cable continuing from this, was 2645' long weighed 2.619 lbs. or 0.99 lb. per foot, and contained 7 #14 B+S. jute-covered wires. The resistance of this length was 6.842Ω @ 17° C. by Schenck and Tests and a capacity of 0.100 μF (one wire against all the others + sheath). This represents 13.5Ω and 0.199 μF per mile. It is C.I. #192 and cost £0.398 or @ 60% off £0.156 per foot. The 7 wires were connected to 7 of the wire in the first cable, leaving 7 more vacant. The cable was suspended 6 feet from the ground on the paling, except at road crossings and at one end where 600 feet being in excess, it was laid back doubled for 200'. The cable was also closed at 4 joint boxes.

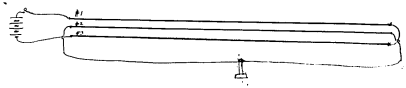
The 7 wires brought with both ends into the Galvanometer room had a total length of 3610 feet, and had a mean resistance of 13.3 Ω each, varying from 13.29Ω to 13.38Ω. The insulation between the wires and between each to ground was practically perfect. The capacity of one wire to all the others and sheath was 0.135 μF. The wires were numbered No 1 to 7. A current was sent on each #1 of 0.5 amp: from 4 storage cells and a relay of 1.95Ω resistance connected to each other wire such as #3. Sending on the #1 produced disturbance on #3 relay, and worked as sounder. The relay is a polarized instrument just responding to a current of 6 milliampères under the adjustment tried. When a telephone was substituted for the relay, the disturbance was loud. This telephone had a res. of 74.9Ω and an inductance of 103 millihenrys. The connections are shewn in Fig. 1.

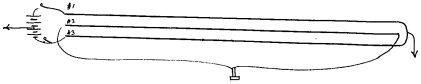
The next experiment was the employment of a return-circuit and double opposite circuits. This reduced the inductive disturbance in the telephone nearly to zero.

Next, an artificial line was worked, (without the cable). It was made up of twelve condensers and resistances. Each resistance was 200Ω of 4.5 wire, and each condenser about 1.8 μF. The total capacity was 20.7 μF and total resistance 2395Ω. Two relays in this circuit, one at each end. Next 10 more relays were inserted in the line at different distances making a total resistance of 5865Ω. The twelve-relay line worked with the ordinary W.U. Relay at a speed of 30 words a minute. Steady current 0.020 amp.

Finally, the artificial line was increased by 2355, and 16.265 μF making a total of 8220Ω and 37 μF with 12 relays. This line worked at about # 15 or 20 words per minute from one end to the other, corresponding to a cable 200 miles long.







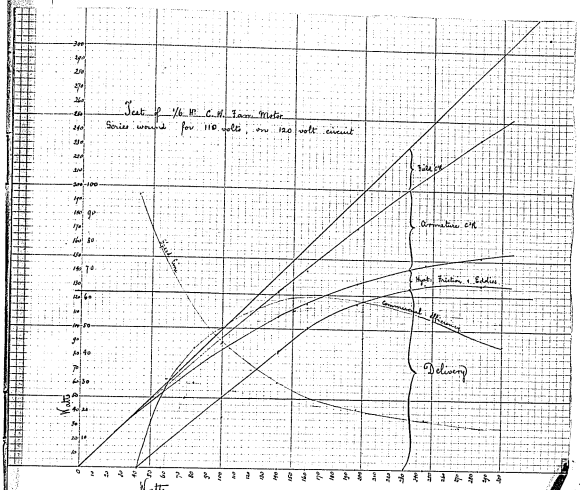
The telephone just readers audible a current of 4 microamperes. This strength of current passing through the telephone, makes a click just audible when a short circuiting key round the terminals is opened

Test of the ½ H.P. B.W. Fan Motor Marked

The weight of this motor is 27 3/4 lbs. It is series wound, and the armature

The motor was coupled to the Edison 500. watt 500. volt motor.

No. of Test	P.D. at the terminals	Ampere	Energy in Motor	Rev. of field	Drop in field	P.D. at armature	Energy in field	Energy in armature	Rev. of armature	Drop in armature
1	117	0.067	0.346	40.5	7.1	2.5	114.5	8.756	396	12.56	4.35
2	120.	0.105	0.557	66.9	28.5	17.5	102.5	9.78	57.15	13.1	7.3
3	119.5	0.130	0.671	80.15	24.	21.7	97.5	14.6	65.55	13.5	9.1
4	120.5	0.163	0.841	101.3	30.3	26.	94.5	21.9	79.4	13.9	11.7
5	119.4	0.227	1.172	139.9	7.2	12.	107.4	14.1	125.8	12.75	14.9
6	119.	0.260	1.342	159.7	7.7	13.5	105.5	18.1	141.6	13.6	18.3
7	119.5	0.318	1.641	196.1	8.1	15.	104.5	24.6	171.5	14.4	23.6
8	119.5	0.397	2.044	244.9	8.4	17.5	102.	35.9	209.	14.5	30.3
9	120.	0.458	2.363	283.6	8.6	20.	100.	47.3	236.3	15.2	38.9
10	119	0.047	0.243	28.9	27.5	6.7	112.3	1.62	27.3	12.56	3.05



Type T # 6446, 1600 rpm. 1.75 amp. 110 volts. (by)

...and 12... ...th changes from field coils in parallel. Res. coil. Fields in series 40.06 ohms 27.5
- - parallel 19.66 7.10
Armature 12.56

Energy in watts	Effort	Speed rpm.	Speed r.p.s.	Balance Error 0-4	Moment	6765 K Moment	Delivery	Friction Hyst. + Dis.	Efficiency	Load
1.5	38.1	5800	97	-	-	-	0	38.1	-	Hyst. slack light
4.06	53.1	1990	33.2	50 to 24.3	2165	1.335×10⁷	44.32	8.8	0.662	a little 2nd
6.09	59.5	1760	26.	1000 to 25 1000 to 0	2750	1696.	44.09	15.4	0.580	½ ½
9.83	69.6	1310	21.8	100 to 25 50 to 23	4100	2525.	55.10	14.5	0.647	1 -
17.5	108.3	1810	20.2	100 to 25 50 to 23	4700	2898.	87.5	20.8	0.626	1 -
24.5	117.1	1540	25.7	200 to 50 100 to 25	6350	3915.	108.6	16.5	0.630	1 ½
38.8	132.7	1290	21.5	200 to 25 100 to 12	8850	5457.	117.3	15.4	0.598	1 ½
62.1	146.9	1060	17.7	200 to 5 100 to 2	12,150	7490.	132.6	14.3	0.541	2 ½
84.9	151.4	900	15	200 to 0 100 to 0	14,300	8816.	132.2	19.2	0.466	2 ½
0.74	2.56	3800	63.3	-	-	-	0	36.6	-	Low speeds unsatisfactory

Motor Driving 15¾" fans

Slow Speed 1370 rpm Ohms 0.170 amp 0.877 P.D. 149 volts 104.3 watts
High - 1700 .. - 0.259 - 1.336 - 117.5 - 157 watts

When fitted with 12" fans 6 blades regular Edison General type

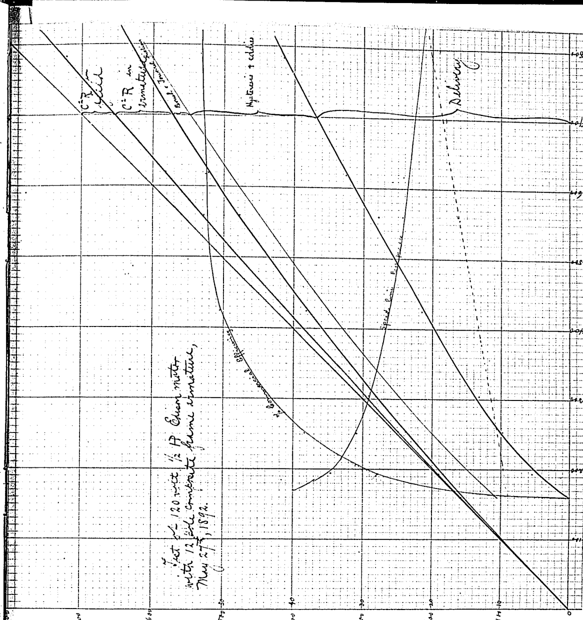
Slow speed 1720 rpm - 0.125 - 0.645 121 - 78.0
High - 2130 .. 0.190 - 0.980 - 118.6

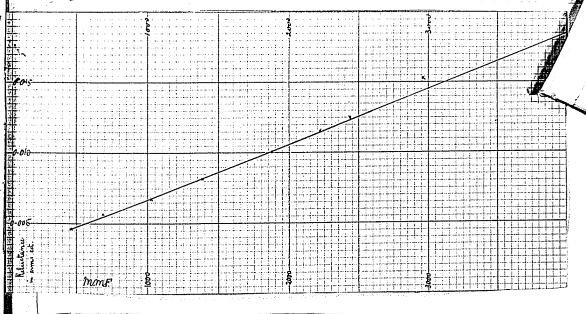
Res: of motor @ 44°C on arm: (hot) 3.77 ω
" " " @ 15°C " " " 3.47 ω field 1.28 – 2.19 ω
1.39 2.38

No. of Obs.	P.D. at motor terms.	Obach	Amp.	Energy absorbed by motor	Res: of field	Drop in field	Energy in field	Energy entering armature	Resistance of arm:	P.D. at arm: terms.	Drop in arm.	EMF of arm.
1	122	0.255	1.315	160.4	1.28	1.6	2.2	158.2	2.19	120.4	2.9	117.5
2	118.7	0.317	1.636	194.2	1.29	2.71	4.1	190.1	2.20	116.7	3.6	112.6
3	120.	0.410	2.116	253.9	1.30	2.75	5.8	248.1	"	117.3	4.7	112.6
4	119.5	0.493	2.545	304.1	1.31	3.33	8.5	295.6	.	116.2	5.6	110.6
5	121.5	0.678	3.500	425.2	1.33	4.65	16.3	408.9	2.25	116.8	7.9	108.9
6	119.	0.910	4.696	558.8	1.35	6.34	29.8	529.0	2.30	112.7	10.8	101.9
7	121.	0.990	5.110	618.2	1.37	7.0	35.8	582.4	2.34	114.	12.0	102.
8	118.5	1.280	6.605	782.6	1.39	9.2	60.6	722.0	2.38	109.3	15.2	94.1
9												

Test of 120 = volt motor for speed and Reluctance
With 12 poles in the armature, and 0.020" (0.05 cm) airgap.

No. of Obs.	P.D. at Armature	Current in Obach	field amp.	amp. MMF	Drop in Armature	EMF of arm.	Speed Rpm.	Rps.	EMF per revs per sec.	F.	B	R
1	118.5	0.83	4.28	2959	2.5	116.	1690	28.2	4.11	194,600		·0152
2	118.5	1.14	5.88	4065	2.4	116.1	1630	27.2	4.27	202,200		·1201
3	119.6	0.682	3.52	2434	2.3	117.3	1720	28.7	4.07	193,700		·01257
4	120.	0.620	3.20	2212	2.3	117.7	1750	29.2	4.03	190,800		·0116
5	120.5	0.526	2.71	1874	2.3	118.2	1825	30.4	3.89	184,200		·01011
6	121.	0.392	2.02	1397	2.3	118.7	1988	33.1	3.59	170,000		·00822
7	121.	0.292	1.51	1044	2.4	118.6	2200	36.7	3.23	153,000		·00612
8	120	0.196	1.01	698	3.0	117.	2700	45.	2.60	123,100		·00511
9	117	0.127	0.655	453	5.2	111.8	3220	53.7	2.08	98,480		·00461





Test of Edison Composite Frame 110-volt A ½ H.P. Motor. May 27th

70

The previous test of this motor is given on page 58. Since that time the number of segments has been increased from 6 to 12. The armature was floated in the tank, and coupled to the other 500-volt motor

Load	Speed of motor r.p.s.	Input in watts less loss in resistance	C.M. in armature	Effort	Balance	Moment	6.66 × Moment	Damping	Friction	Efficiency Commercial	Load
					20 in. = 1'						
	40	2.938	3.V	154.4				-	154.4	0	Light running
4/5	34.5	3.263	5.87	184.2	184 in 20 in = 9.2 lbs	2550	1.872 × 10³	54.2	130.	0.279	eighth
1/2	31.	3.63	9.9	238.2	238 in 20 in = 11.9 lbs	5100	3.745	97.5	140.7	0.384	1/2 SEE
3/4	24.2	3.787	14.3	281.3	281 in 20 in = 14.05 lbs	7350	4.872	122.3	149.0	0.435	2/4
1	26.7	4.08	27.6	381.3	381 in 20 in = 19 lbs	13,050	8.045	214.8	166.5	0.505	2/4 full
1 1/4	24.3	4.492	50.7	478.3	478 in 20 in = 23.9 lbs	18650	11.58	279.4	198.9	0.509	2 . 8
1 1/2	24.2	4.215	61.3	521.1	521 in 20 in = 26.05 lbs	21,850	13.97	325.9	195.2	0.527	2 . 6
1 3/4	21.7	4.336	100.0	622.0	622 in 20 in = 31.1 lbs	31,100	19.18	416.2	205.8	0.532	4 . 9

log 14·69 = 1·167028
2·104 = 0·3230457
0·8439761 — 6·98194
7·6850899
0·0455562 — 8·88968

log 102·21 = 2·009+9339
99·95 = 1·9997828
0·0097089 — 1·022611

log 0·2104 = 7·3230457
0·009 7106 — 2·05743
7·313 33351 — 0·205748

log 0·205748 7·31333351
· 304797 4840107
7773478
· 64516 8096674 — 9·72006
1876784 — 9·72027

143652 — 15731112
0048203 — 1·42059
1524909 — 1·42066

161594 — 2084250
0048203 — 1·59705
2036047 — 1·5981

log 10·3 = 2·0265336
10·83 = 2·0204859
0·0060476 — 1·014023

log 205748 3133351
0060477
·3072874 — 0·0202903

· 972027 9876784
0060477
9816307 — 9·58585

· 0·9866 9941411
143652 1573112 — 1·41729
1514523 — 1·41727

· 1·61594 20842 50
9941411
2025661 — 1·59428

log π = 0·4971499
÷ = 0·6020600
1·8950899

log 1·469 = 1·1670218
0·009 7106
7·1573112 = 0·143652
0·143634

2·3133351
1·8950899
3·5182452
6·2084250 = 1·61594

log 10·6 = 2·0253057
104·83 = 2·0204859
0·0048198 — 1·011161

205748 — 3133351
0048203 — 2·03459
3085148 — 2·03477

9·72027 — 9876874
0048203 — 9·6122
9828671 — 9·61319

143652 — 1573112
0060477
·1512635 — 1·41665

161594 — 2084250
0060477 — 1·59425
2023773 — 1·59359

1·0
0·0060476 7
0·9939523 3 — 0·985171

205749 — 3133351
9941411
3074762 — 0·0202991

9·72027 — 9876784
9941411
9818195 — 9·59098 / 9·59002

Red numbers are those independently computed by Mr G. A. Hamilton.

On the Matthiessen Standard of Conductivity

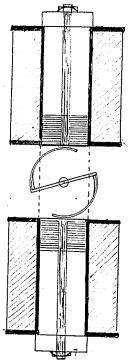
(71)

The resistance given by Matthiessen for a hard drawn copper wire one metre long and weighing one gramme is 0·1469 B.A.U. @ 0°C.
Also the resistance of a hard drawn copper wire 1 metre long and one millimetre in diameter is 0·02104 B.A.U. at 0°C.
From this the "metre-millimetre" wire weighed $\frac{14·69}{2·104}$ = 6·98194 gms.
And its specific gravity = $\frac{6·98194}{0·7854}$ = 8·88968.
The relative conductivities has given for hard and soft copper are 99·95 and 102·21. A ratio of 1·022611.
The resistance of the soft copper metre gramme @ 0°C is 0·143652 B.A.U.
" " " metre millimetre @ 0°C " 0·0205748 . . .
" " " cubic centimetre @ 0°C " 1·61594 × 10⁻⁶ . . .
" " " mil foot @ 0°C " 9·72027 . . .

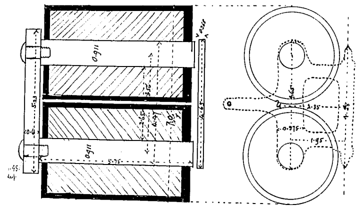
The factor of conversion from the B.A. to Legal ohm is 1/1·011161
From this the metre gramme @ 0°C is 0·142066 legal ohms.
" " metre millimetre " " 0·203477 " "
" " cubic centimetre " " 1·5991 × 10⁻⁶ " "
" " mil foot " " 9·6132 " "

The factor of conversion from the B.A. to New Standard ohm is 1/1·014023
From this the metre gramme @ 0°C is 0·141665 New ohms
" " millimetre " " 0·0202903 " "
" " cubic centimetre " " 1·59359 × 10⁻⁶ " "
" " mil foot " " 9·5859 " "

If however the factor from the B.A. to New Standard is 0·9966
The value of the metre-gramme @ 0°C is 0·141727 New ohms.
" " metre-millimetre " " 0·020299 " "
" " cubic centimetre " " 1·59428 × 10⁻⁶ " "
" " mil foot " " 9·59002 " "

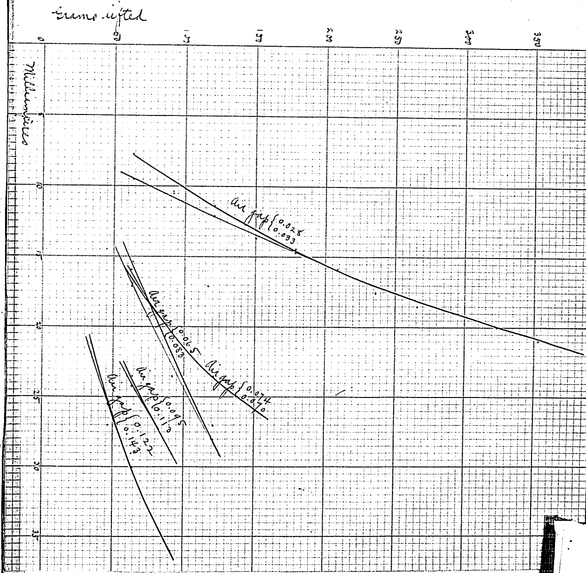


Section of W.U. Relay through core centers.



Weight of magnet	420 gms.
" " armature	16.7
Moment of Inertia of the armature about its axis }	135.0 cm²gms.
Cross section of cores	0.652 cms²
" " armature	0.261 " at narrowest part. 0.0405 sq. in.
" " yoke	0.888 "
Radius of retractive forces on hook	2.35 cms.
Mean rad. of attractive forces	1.95 "
Radius of contact point	4.28 "
Resistance @ 15°C.	139 ω. (two coils in series)
Virtual rad. of armature / Radius of gyration }	2.840 cms.
Winding	28 layers 3430 turns on ~~oak~~ spool. 30 layers 4070 turns on other
Wire	# 29 B&S. 0.0113" d.s.c. to 0.0135"
Total.	58 layers 7500 turns

This relay rewound on the 22nd June over the same cores, but on a hard rubber shell with # 27 B.W.G. / 26 B&S. wire 0.0159" s.c. to 0.018" Total 52 layers 5720 turns 2860 turns on each spool (26 layers of 110 turns each).
Res. of relay 53.52ω @ 30°c.



Measurements with a Western Union Relay.

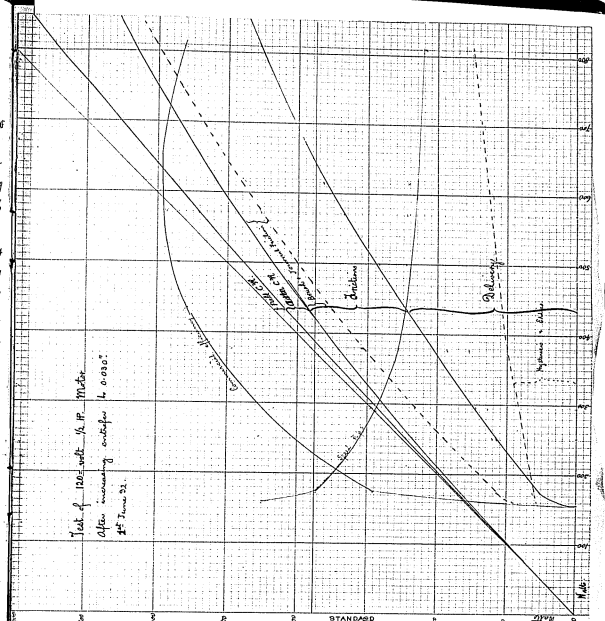
The attractive force exerted by a standard Western Union Relay was measured by setting the relay on a vertical board, with its armature in the horizontal plane, and attaching a bucket to the hook to be so made in place of the spring, a definite load. The full obtained for different current strengths in the coils was thus determined. The corresponding distance between pole and armature — the ontafes — was measured with a steel wedge. It was never quite equal on both sides, so the wedge was used at each pole. The ontafes was observed with the current off, and the relay had to lift the armature up from this distance.

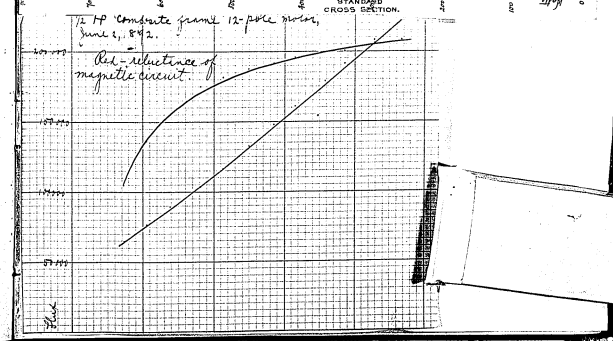
Ontafes	Total Wt Lifted	Single direction current	Ampere turns		Current on reverse direction						
		Plug in set			Plug in set	Current	AMPERE TURNS				
0.065 / 0.093 (0.079)	63	590	0.0153			440	0.0171					
	92	390	1.022			320	0.0235					
	121	270	0.128			280	0.0270					
0.025 / 0.038 (0.032)	63	1800	0.0077			820	0.0095					
	92	710	0.0103			700	0.0105					
	121	610	0.0113			610	0.0121					
	150	540	0.0137			540	0.0137					
	179	510	0.0144			500	0.0147					
	208	470	0.0158			470	0.0158					
	237	420	0.0175			420	0.0175					
	266	400	0.0185			400	0.0185					
	295	385	0.019			385	0.019					
	324	364	0.020			364	0.020					
	353	349	0.021			349	0.021					
	382	218	0.0217			218	0.0217					
0.095 / 0.113 (0.104)	63	286	0.0235			211	0.0263					
	92	173	0.029			173	0.029					
0.122 / 0.143 (0.132)	63	305	0.029			297	0.030					
	46	325	0.027			325	0.027					
	34	415	0.0212			405	0.0218					
	92	250	0.036			250	0.036					
0.064 / 0.070 (0.067)	63	441	0.0158			511	0.0169					
	92	435	0.0203			435	0.0203					
	121	375	0.0235			375	0.0235					
	150	339	0.0256			334	0.026					

Time	Volts at mains	Shunt	Amp.	Energy absorbed in watts	Rev. of field	Drop in Volts	Ratio $\frac{E.M.F. \text{ of armature}}{\text{Energy entering armature}}$	Energy entering armature	Resistance of armature	P.D. at armature terminals	Drop in Volts
13.00	125.8	0.242	1.249	156.8	1.28	1.6	2.0	154.8	2.19	123.9	2.7
14.30	119.4	0.252	1.455	173.1	-	1.9	2.7	170.4	2.19	117.1	3.2
14.35	119.	0.409	2.111	251.2	1.30	2.7	5.8	245.4	2.23	116.3	4.7
14.40	119	0.480	2.477	294.8	.32	3.3	8.1	286.7	2.26	115.7	5.6
14.43	119.	0.615	3.174	377.7	.31	4.3	13.5	364.2	2.30	114.7	7.3
14.47	119.5	0.705	3.638	434.7	.36	4.9	18.0	416.7	2.33	114.6	8.5
14.51	121.	0.800	4.128	499.5	.38	5.7	23.5	476.	2.36	115.3	9.7
14.55	121.	0.915	4.722	571.4	.40	6.6	31.2	540.2	2.39	114.4	11.3
15.00	120	0.995	5.135	616.1	.42	7.3	37.4	578.7	2.42	112.7	12.4
15.05	121	1.310	6.788	810.8	1.44	9.7	65.8	745.	2.46	111.3	16.6

The following speed observations were also made:-

Ref. No.	Shunt in Volts	Current in Field	Mom.	Strength of field in cent.	Amp.	Volts drop in Arm.	Drop in Arm.	Emf of arm.	Emf per rev. per sec.	Rev. per min	Rev. per sec.	F	B	R
1	1.310	6.700	4674	50°	0.899	112.	2.0	120	4.40	1493	27.3	2.032×10^{10}		2211×10^{3}
2	1.20	6.192	4281	49.30°	0.893	110	1.9	118.1	4.39	1612	26.9	2.078.		2260.
3	1.08	5.573	3853	49°.	0.867	110	1.9	118.1	4.25	1665	27.8	2.013.		1949.
4	1.00	5.160	3568	49°	0.867	110	1.9	118.1	4.22	1680	28.0	1.999.		1735.
5	0.883	4.557	3151	48.30	0.852	108	1.9	118.1	4.14	1710	28.5	1.960.		1615.
6	0.798	4.118	2847	48.	0.867	110	1.9	116.6	4.06	1720	28.7	1.923.		1481.
7	0.700	3.613	2497	48.	0.838	106	1.8	116.7	3.96	1770	29.5	1.875.		1333.
8	0.595	3.071	2123	49.	0.867	110	1.9	116.6	3.85	1820	30.3	1.823.		1165.
9	0.508	2.620	1813	49.30	0.883	112	1.9	116.6	3.69	1895	31.6	1.747.		1038.
10	0.389	2.006	1388	51°	0.931	118	2.0	116.5	3.28	2130	35.5	1.552.		843.
11	0.245	1.522	1052	53.15	1.01	128	2.2	115.9	2.90	2400	40.0	1373.		766.
12	0.200	1.032	713	61.	1.360	172	3.0	111.0	2.32	2870	47.8	1099.		649.

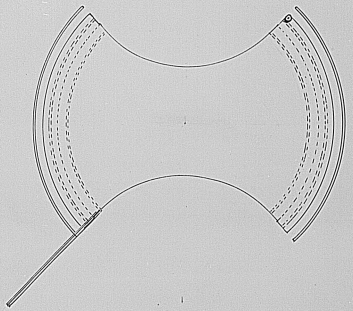


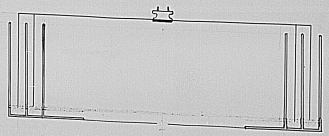


Tests of 12-poled armature ½ HP. Composite Frame Motor 1st June
after grinding surface of armature, to as to make the
entrefer 0·030".

The motor was belted by the flexible rod to the 500-volt ½ HP. motor
and the following results obtained.

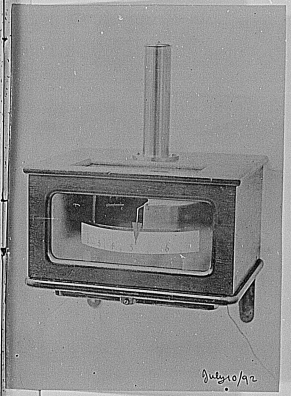
Speed R.P.M.	Volts per bar	E.M.F. in armature	Effort	Balance lbs.	Moment	Effort × Moment	Velocity	Friction	Commercial efficiency	Load
1645	2·63	3·4	151·4	— —	—	—	0	151·4	0	Light
1735	3·06	4·6	165·9	200 @ 40 / 200 @ 19	22200	1·357 X10⁷	50·5	95·3	0·292	Complete
1923	3·45	10·4	235	400 @ 15 / 400 @ 25	57500	3·595 ·	114·5	120·5	0·486	10F am.
2145	3·73	13·9	272·8	500 @ 7 / 500 @ 25	70250	4·397 ·	128·2	144·6	0·495	2 "
2356	4·16	23·1	341·1	500 @ 10 / 500 @ 21 / 200 @ 20	117500	7·244 ·	186·9	154·2	0·495	2 6
2475	4·29	30·8	385·9	400 @ 16 / 400 @ 25	154250	9·832 ·	243·4	142·5	0·560	2 3
2417	4·27	40·2	435·8	500 @ 12 / 500 @ 25	181250	11·52 ·	284·5	151·3	0·570	2 5
2435	4·21	53·4	556·8	500 @ 5 / 500 @ 20 / 500 @ 20	222500	13·72 ·	336·1	150·7	0·588	2 7½
29	4·11	64·0	514.	200 @ 10 / 200 @ 25 / 1000 @ 20	247500	14·98 ·	368·5	148·5	0·593	2 10
2617	4·36	112·6	620·4	500 @ 23 / 1000 @ 20 / 1000 @ 23	347500	21·06 ·	457·0	175·4	0·564	5 "



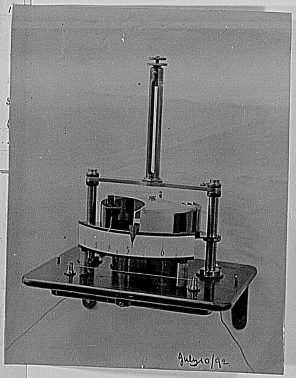


The torsional moment of the suspension at 30° limit =

$$M = \frac{28.5 \times 981 \times 0.183 \times 0.183}{13.1} = 7.144 \times 10 \text{ cm dyne}$$



July 10/92



July 10/92

Pl. 1
Pl.

Trial scale of the 600. volt Statie Voltmeter June 3rd 92

The distance between the suspension wires (0.002" piano) is 0.361 above and 0.37 below
The length of the wires is 13.1 Frames. The Mass of the whole suspension
is 28.5 gms(Rowland). The distance between channels is 0.52. The angle
subtended by the channels is . The thickness of the vanes is 0.039
The following observations were made of the scale indications.

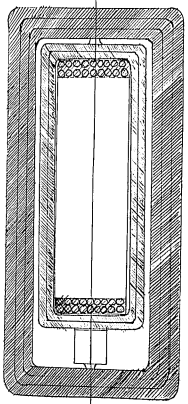
1.15	3.40 2.50	3.57 2.40	3.70 2.30	4.02 2.15	4.20 2.00	4.55 1.80	4.90 1.55	5.35 1.30	5.90 1.05	6.3 .90	6.58 .84
0	323.3	345.2	364.1	391.2	415.1	440.2	462.1	489.3	519.2	553.0	599.0
0	69.3	67.6	78.3	76.6	81.3	86.2	90.5	96.0	101.7	108.3	117.3

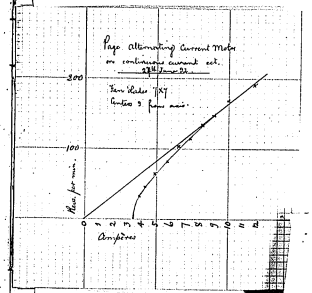
Res. of Vento. 2074 ω. Res. of ext 10,592 Ratio 5.107

Test made for Efficacy of Edison Transformer Patent June 3rd 92

(continued from p. 62
The storage cells used in the first trial were doubled in capacity by
using another pair of the same size of lead plate in each jar. These
were "formed" in the same manner as the others. The following
observations were made of the transformation with the commutator
running.

Potential changing cells in series	Time given cells charging in series	Mean Amps	Apparent Watts absorbed by cells	Watts as recording Voltmeter	Ohms in circuit incl. cells	Amps Mean	Apparent efficiency of cells	Effic. efficiency
12.2	3'.10'	0.415	50.7	19.5	0.147	0.758	14.8	0.292
12.2	3'.20'	0.439	53.6	16.7	0.275	1.42	23.7	0.442
12.4	4'.20'	0.571	70.8	19.1	0.285	1.06	20.2	0.286
12.5	4'.16'	0.549	68.6	20.0	0.207	1.07	21.4	0.312
12.3	4'.40'	0.615	75.6	18.3	0.287	1.07	19.6	0.259
12.2	5'.0" 4 44"	0.725	88.8	14.7	0.418	2.16	31.75	0.361




Page Alternating Current Motor
no continuous current acc.
Form Under 1247
Curtain 3 Pulse wave.
300
100
Revs per min.
0
Amperes

Design for an alternating current motor meter in the Edison patent case.

The size of wire forming the inner coil is # 13 B.W.G. 0.095" s.c.c. & 0.103". Nine turns wide and two layers make 18 turns in each of the movable coils. Each turn will be 1 foot, so that the length in each coil will be 18' @ 0.001144 = 0.02 ω. The outer coil will be composed of # 12 B.W.G. 0.109" s.c.c. & 0.120". There will be 3 layers and 12 turns to each or 36 turns. Each turn = 1.5' so that there will be 54' of wire, @ 0.0008688 ω = 0.047 ω. The total resistance being 0.067 @ 20° C. and the total drop at 10 amp. 0.67 volts in ar.

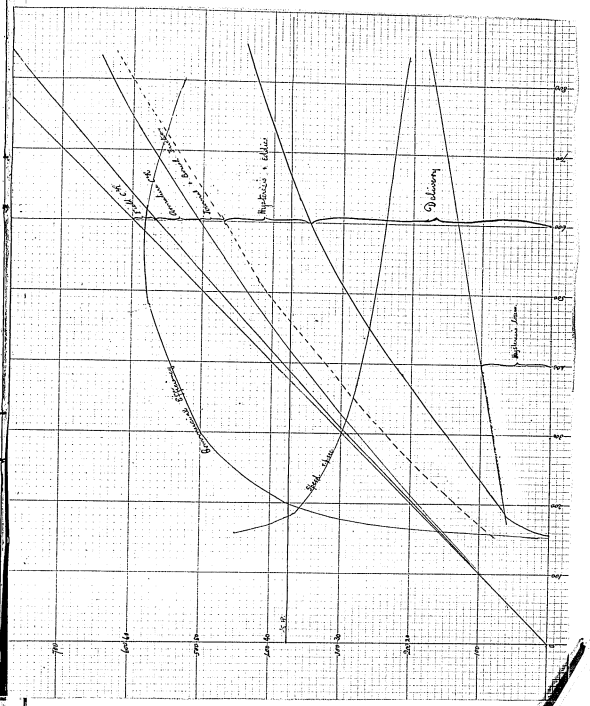
The weight of the two movable interior coils is 36 × 0.02735 = 0.9847 lb.

The instrument, as first tried, had too small a field, and gave trouble at the commutator owing to the existence of two separate circuits. By employing # 17 B.W.G. 0.058" s.c.c. & 0.066", each of the four inner coils can be formed of 3 layer in 9 turns, or 27 turns. The resistance of the 27' = 0.083 ω. In all 108' and 0.013 ω. The total resistance will be 0.13 ω. The width of each coil will be 9 × 0.066 = 0.594" and the thickness 3 × 0.066 = 0.198".

On completion, the resistance of the instrument was 0.1285 ω @ 25°C. It was tried on 120 volt continuous current circuit with following results:

No. of Obs.	Lamps in circ.	Ohms	Amp.	Time	Revs.	R.p.s.	Revs. per amp.	R.p.s. per amp.
1	8	0.605	3.35	bosom	Just stops			
2	9	0.720	3.716		33	0.55	8.882	
3	10	0.812	4.190		45.7	0.762	10.910	
4	12	0.935	4.929		65	1.083	13.19	
5	14	1.106	5.707		81	1.35	14.19	
6	16	1.260	6.502		103	1.72	15.84	
7	18	1.418	7.316		115	1.92	15.72	
8	20	1.584	8.174		134	2.23	16.39	
9	22	1.746	9.008		148	2.47	16.43	
10	25	1.940	10.01		168	2.8	16.78	
11	30	2.286	11.80		190	3.17	16.10	

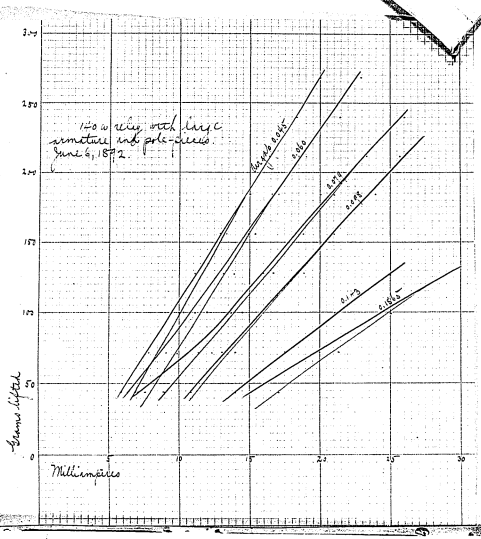
Time	Volts at motor brushes	Ohmich	Ampg.	Energy supplied by motor	Res. of field	Drop in field	C.M. Ins of energy in field	Energy entering armature	Res. of armt.	P.D. at armature terms	Drop in armt.	Eff.
.	125·5	0·242	1·249	156·8	1·28	1·6	2·0	154·8	2·42	123·9	2·7	·1212
12·00	119·4	0·309	1·545	184·8	1·34	2·1	3·21	181·6	2·72	117·3	3·7	·1016
·15	119·4	0·378	1·951	232·9	1·36	2·7	5·18	227·7	2·45	116·7	4·2	·1119
·18	119·0	0·485	2·503	297·8	1·38	3·5	8·65	289·1	2·48	115·5	6·2	·1043
·24	119·4	0·708	3·653	436·2	1·39	5·1	18·55	417·6	2·50	114·3	9·1	·1052
·30	119·4	0·975	5·031	600·7	1·40	7·0	35·4	565·3	2·52	112·4	12·7	·0947
·34	120·5	1·170	6·036	727·2	1·41	8·5	51·4	675·8	2·54	112·0	15·3	·0947
·39	120·5	1·340	6·914	833·0	1·42	9·8	67·9	765·1	2·56	110·7	17·7	·0920



Test of ½ H.P. Edison Composite Frame Motor.

The only change made since the last test has been the insertion of platinoid wires 0.018" in diam: between the commutator and the armature. This wire has a resistance of 0.73 ω per foot and three ~~sets~~ of 0.2' in each. The resistance of this length is 0.150 ω and the resistance of each section in the armature is 0.367 ω so that each local circuit has been increased from 2.367 ω to 0.667 ω or in ratio of 1.818. This wire in the open air carries 8.3 amp. with visible luminosity — red hot. It burns away at 11.6 amp.

Speed r.p.s.	Volts per 100 rev. per sec.	c²R in armt.	Effort	Coil Resistances	Moment	6.165 × Moment	Delivery	Friction	Commt efficiency	Load
45	2.64	3.4	151.4	- -	-	-	-	151.4	0	
39.00 34.7	3.10	5.80	175.8	{50 Ω - 4ω 200 " 13"	2800	1.726×10⁴	63.3	112.5	0.364.3	Enfield
1980 33.0	3.39	9.32	218.4	{50 Ω 13" 200 " 50	4750	2.929 -	96.7	121.7	0.4.65	S.E.F. 1
1800 30.	3.64	15.5	273.6	{200Ω 35" 50 " 8	7900	4.871 -	146.1	127.5	0.490	" 3
1610 26.8	3.92	33.4	384.2	100Ω 15	15000	9.248 -	247.8	136.4	0.568	Loaded
1460 24.0	4.15	63.8	501.5	{100Ω 12.5 100 " 3.4	23375	14.41 -	311.5.8	155.7	0.576	"
1360 22.3	4.34	92.5	583.3	{100Ω 3.4 200 " 1.8 50 " 5	27150	17.73 -	395.3	188.0	0.544	"
1250 20.8	4.47	122.4	642.7	{100Ω 3.4 200 " 1.8 50 " 0.4	33800	20.84 -	448.4	209.3	0.520	" 5


150 ohm relay with large armature and pole-pieces.
June 6, 1872.
Grams lifted
Millimpères
3.00
2.50
2.00
1.50
1.00
.50
0
5
10
15
20
25
30
distant 0.035
0.040
0.045
0.050
0.055
0.060

Test of W.U. neutral Relay after exchanging the Armature.

Two pole faces of annealed wrought iron were screwed on to the relay cores, and the armature was made of a sheet of annealed wrought iron 0.107 thick. The winding, and all the arrangements were left unaltered. The test was made as on p. 73.

Distance	Total Wt Coils	Single direction of Current: Current	MMF	Reluctance	Both directions of current: Current	MMF	Reluctance
0.193	43·5	0·0151			0·0171		
0.192	71·5	0·020			0·0213		
0.185	99.6	0·025			0·0250		
	127·6	0·0229			0·0298		
0·185	127·6	0·025			0·025		
0·141	99.6	0·0211			0·0211		
0·143	71·5	0·0175			0·0175		
	43·5	0·0114			0·0114		
0·098	43·5	0·0108			0·0103		
	71·5	0·0131			0·0140		
	99.6	0·0160			0·0168		
	127·6	0·0195			0·0188		
	155·7	0·021			0·021		
	183·7	0·0239			0·0239		
	211·7	0·0257			0·0257		
0·079	~~239·8~~	0·0233			0·0233		
	~~211·7~~	0·0260			0·0260		
	~~183·7~~	0·022			0·021		
	~~155·7~~	0·0188			0·0188		
	~~127·6~~	0·016			0·0167		
	~~99.6~~	0·0137			0·0146		
	~~71·5~~	0·0114			0·0123		
	43·5	0·0071			0·0089		
0.060	43·5	0·0064			0·0077		
	71·5	0·0091			0·0099		
	99.6	0·0112			0·0120		
	127.6	0·0132			0·0139		
	155·7	0·0149			0·0162		
	183·7	0·0166			0·0171		
	211·7	0·0185			0·0191		
	239·8	0·0214			0·0212		
	267.9	0·0229			0·0229		
0·045	267·9	0·020			0·020		
	239·8	0·0183			0·0183		
	211·7	0·0164			0·0164		
	183·7	0·0150			0·0150		
	155·7	0·0128			0·0133		
	127·6	0·0112			0·0147		
	99.6	0·010			0·003		
	71·5	0·0078			0·0086		
	43·5	0·0059			0·0069		

The new armature makes 210 complete vibrations per min = 3·5 per sec.

$f = \frac{4.46 \times 981}{(3540)} = 2800$. The mass of the armature is 13·4 gms

The moment of inertia is 73·6 cm²gms.

Test of 1000-volt static voltmeter June 7th 92.

The following scale was measured for the 1000-volt meter.

Outline of Specifications proposed for the Philadelphia Telegraph Line. June 10th 92.

The size of copper wire #14 B.W.G. 0.0641" covered to 0.1891" with paper in three coats if possible. The first coat japanned, the others soaked in paraffin wax. 14 wires layed up in one cable.

Weight of wire per foot 0.01245 lbs. per mile 66.74 lbs.
" 14 wires " ~~foot~~ 0.1743 lbs, " " 934.3 "

Cost of copper in cable per foot @ $0.16 = $0.02789 per mile $149.50
Resistance of wire per foot = 0.002513Ω per mile 13.27Ω @ 20°C or 13607 mf
Estimated capacity of one wire to ground 0.2 mf per mile.
Capacity × Insulation for one mile = 2736
" " " 100 miles = 27.360.
Approximate internal diameter 0.85"
" external " 1.02" } Thickness of lead 0.075".

Measurement of the Power needed to operate electrically the Aeolian organ in Mr Edison's house. 8th June.

Current supplied to 1/8 H.P. Perret motor 0.925 amp. varying 0.1
Pressure " " " " " " 115 volts
Energy " " " " " " 106 watts

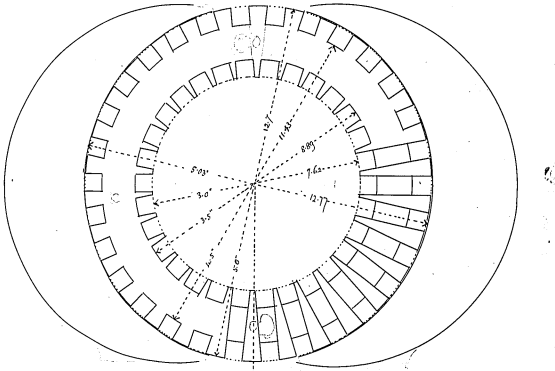
The motor does most work when all the stops are in and the music is not played.
106 watts absorbed by this motor represent 45 to 50 watts delivered, according to our tests of this style of motor.

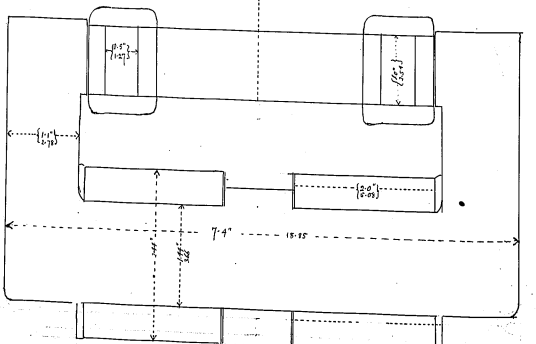
Resistance and Inductance of a Phonoplex Receiver. 8th June.

Res: 99.14Ω. @ 17° C.
Inductance with cover diaphram removed 45.6 mh.
" " cover hung down on poles 116.5 mh.

Torque per ampere = $\frac{100,000 \times 2.70 \times 0.1}{6.28}$ = 42,9700 dyne cms = 438 gm-cms.

= 0.966 lb. ins = 0.380 lb-in-ches





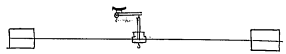
Field winding allows 7th zone to go home of #13 B.W.G. on each spool + spools in multiple

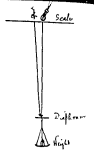
Section of field magnet allows to 13.15 sq/cms.

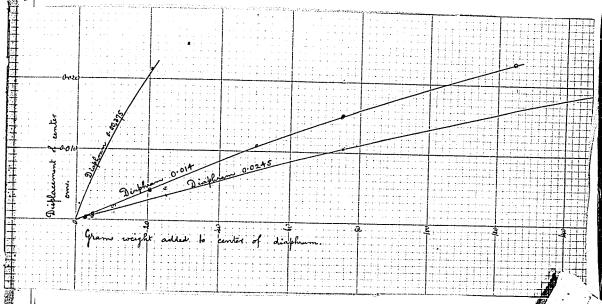
Design for a Phonograph Motor. Battery type.

(80)

Type	Bipolar, series field, gramme ring armature with teeth.		
Speed	400 rpm. 6.6 r.p.sec.		
E.M.F.	1.85 volts.		
Battery	4 Edison-Lalande cells each 0.6 volt 0.03 a.		
Driving E.M.F	2.65 volts		
Current	3 amp		
Drop in battery	0.36 volt		
P.D. at battery terminals	2.29 .		
Drop in leads	0.14 .	0.047 ω.	
P.D. at machine terminals	2.15 .		
Drop in motor	0.30 .	0.10 ω. nea.	
External Diameter of armature	5"	12.7 cms.	Circumference 15.71" 39.89 cms
Groove diameter " "	4.5"	11.43 -	14.14" 35.91 -
Mean " "	4.0"	10.16 -	12.57" 31.92 -
Internal groove " "	3.5"	8.89 -	11.0" 27.93 -
Internal " "	3.0"	7.62 -	9.426" 23.94 -
Depth of teeth	0.25"	0.635 .	
Breadth of armature	1.0"	2.54 .	
Cross section "	1.0 × 0.5 (2.54 × 1.27)	= 0.5 sq/in	3.225 sq/cms.
Breadth of each groove	0.265"	0.673 cm.	
Breadth of each tooth	0.259"	0.658 cm. at outer and 0.493" 0.124 m. at inner circumferences	
Ext. Surface of each tooth	0.259 sq/in	1.671 sq/cm	
Total Winding space section per groove	0.265 × 0.25	= 0.06625 sq/in — 0.673 × 0.635 = 0.4274 sq/cm	
Area of iron surface	8.592 sq/in	55.43 sq/cms.	
Volume of iron in armature	8.592 c.in	140.8 c.c.	
Sp. g. assumed	7.8		
Mass of iron	1098 gms	2.422 lbs.	
Peripheral speed of arm	524" per min,	266 kms	
Thickness of body walls mica	0.010"	0.025 cm.	
Diameter of wire	0.0782"	#15 B.W.G. s.c.c. to 0.080"	
Length of mean turn	0.3'		
Total length of arm	90'		
Total number of turns	270		
Number of turns in each pole	9	three layers of 3 turns each.	
Total weight of wire in arm	1.5 lbs.		
Resistance of winding	0.045 ω @ 20°C.	0.0512 ω @ 60°C	
Total Flux in arm	402,800		
B - -	15,930		
Polar surface on teeth	12 × (1.671 + 0.33)	= 24 sq/cms.	B = 4,300
Clearance + entrefer	0.015"	0.038 cms.	
Reluctance of gaps	$\frac{2 \times 0.038}{24}$	= 0.0032	= 3.2 rel
Total calculated rel:	0.005		
Length of path in arm	4.5"	18 cms section 6.45 - 3 cms × 0.0025.	0.0045
MMF required	581		
Exciting power	422		
Turns	127	64 turns on each spool	
Field winding	4 layers of 16 turns each on spool	#12 B.W.G. 0.109" &c. 8.128	
Depth of winding	0.44"	over insulation 0.50"	
Length of coil	16 × 0.12 - 1.92"	say 2.0"	
Diameter of core	1.44"	3.66 cms.	
Cross sectional area	1.629 sq/in	10.51 sq/cms.	
Estimated Leakage factor	1.5		
Flux in core	154,200		
B in core	14,670.		




Scale
Diaphragm
Weight


Displacement of center mm
Diaphragm 0.0175
Diaphragm 0.014
Diaphragm 0.0245
Grams weight added to center of diaphragm

Measurements of Diaphram Displacements. June 13th 92.

The following measurements were made of the bowing or displacement of circular clamped diaphrams under stresses applied at the center normal to the planes. The diaphrams were of mica in varying thicknesses, and weight were suspended from their centers, the displacement being magnified by a beam of light on a pivoted mirror.

Thickness in Inches	Diam. of Diaphm.	Distance h	Total Wt.	Scale deflection	Deviation pointed from	Corrected Mean deviation	Weight applied gms	Diaphragm constant	Displacement per gm	Appl. for 1 cm. Deflection
0.0140	8.90	0.205	3.3	102.7	1.5	0.75	1.3	0.000128	$\frac{1}{7812.5}$	1.617×10^{-4}
			4.3		3.	1.5	2.3	0.000302	1.305	1.927 -
			7.3		9.	4.5	5.3	0.000691	1.70	2.380 -
			12.3		19.	9.5	10.3	0.001902	1.846	2.584 -
			22.3		41.	20.5	20.3	0.004168	2.022	2.831 -
			52.3		107.	53.5	50.3	0.01071	2.129	2.980 -
			27.3		54	27	25.3	0.005405	2.136	2.990 -
			77.3		154	77	75.3	0.015331	2.033	2.846 -
			127.3		254	127.5	125.3	0.025121	1.845	2.583 -
			177.3		295.	147.0	175.3	0.02893	1.645	2.303
0.0240	-	0.700	22		16	8	20.	0.002469	$\frac{1}{2.79\times10^{-3}}$	3.929×10^{-3}
			77		42.	21.5	75	0.0147	1.960	2.744 -
			152.		76	38	150	0.02598	1.732	2.424 -
0.0245	-	0.763	27		9.5	4.75	25	0.00354	1.416	3.469 -
			77		28	14	75	0.01043	1.391	3.408 -
			152		51	25.5	150	0.0190	1.267	3.103 -
0.00375	-	0.7865	3.3		6	3.	1.3	0.002308	$\frac{1}{1.772\times10^{-3}}$	6.646×10^{-3}
			12.3		35	17.5	10.3	0.01364	1.304 -	4.8918
			22.3		56	28.	20.3	0.0215	1.069 -	3.971
			27.3		65	32.5	25.3	0.02496	$\frac{1}{9.674\times10^{-4}}$	3.702
			52		102	51.	50	0.03917	7.834 -	2.938
			27.		63	31.5	25	0.02420	9.68 -	3.630
			77		128	63.5	75	0.04897	6.528 -	2.448
			152.		182	90.25	150	0.06932	4.622.	1.733

Phonograph Battery Motor Design contd: from page 80.

Diameter of armature 1.94" = 0.5'

Total length of wire 64'

Res: of winding 0.056 ω @ 20°C. 0.0636 ω @ 60°C.

Weight - - 2.3 lbs.

Total weight of wire on motor 3.8 lbs.

Total resistance of motor 0.101 ω @ 20°C 0.115 ω @ 60°C.

Estimated Weight of Fild 3500 gms = 7¾ lbs.

- - - armature 5 -

- - - structure 1 -

Total - motor 13¾ -

Local field produced by two neighboring teeth when the current in the armature is 7 amps

Local reluctance 0.076

Local mmf $\frac{7}{2}\times\frac{5}{2.5}$ = $\frac{4.5}{0.7}$ = 5.625]

Flux 774] = 77.4 y lines per bolt.

In the total pole end mmf $\frac{7}{2}=\frac{1}{0.1}\times 10$, 67.5 y

Reluctance 0.038

Flux 2000 y

Particulars and Test of a Sample of Telegraph Cable Wire received from Schenectady 14th June 1892.

This wire was received in a coil of 15 turns each 12·5 cm. mean diam.; = 587 cms. total length. It was labelled #14 B.S. 1 cent Japan. 1 Wrap of paper, 1 cent of Japan 2 paper. Soaked in paraffine wax. Bare diam 0.170: The insulation resistance of this length after 25 hours immersion in water was about 109,000 ω. & 21,000 ω after 60 hrs.

Thickness of diaphm	Diameter of Diaphram	Distance h	Total Wt	Scale dist. dis.	Deviation proposed	Corrected Deviation	Weight applied	Displacement in Cent	Displacement for 1 gramme	Displacement per 1 gm. per Cent of Jute
0.056	6.0	0.653	3.3	7648	7681	8.5	1	4.367×10^{-4}	4.367×10^{-4}	2.619×10^{-4}
			4.3		2	1	2	0.000873	4.365×10^{-4}	2.619
			7.3		4.5	2.25	5	1.964×10^{-3}	3.928	2.357
			12.3		9	4.5	10	3.928	3.928	2.357
			22.3		17	8.5	20	7.42	3.71	2.226
			52.3		35	17.5	50	15.28	3.056	1.834
			27.3		19.5	9.75	25	8.512	3.405	2.043
			77		47.5	23.8	75	20.78	2.771	1.663
			102		58	29	100	25.32	2.532	1.519
0.010	6.0	0.7295	27		18	9	25	8.78	3.512	3.512
			52		29	14.5	50	14.14	2.828	2.828
			77		38.5	19.25	75	18.78	2.504	2.504
			102		46	23	100	22.44	2.244	2.244
			152		58	29	150	28.29	1.886	1.886
0.0235	6.0	0.662	27		5	2.5	25	2.138	0.855	2.080
			52		11	5.5	50	4.869	0.9738	2.288
			77		16.5	8.25	75	7.302	0.9736	2.287
			102		21.5	10.75	100	9.516	0.9516	2.236
			152		31	15.5	150	13.72	0.9147	2.150

It would appear from these results that to a first approximation and for small displacements of the diaphragm this is expressable by the formula

$$d = k \cdot \frac{r}{t} \cdot p$$

where d is the displacement of the centre due to a stress applied centrally in a direction normal to the planes. cms.

r is the radius of the diaphragm cms

t " " thickness " " " cms.

p " " pull exerted

If p be expressed in grammes weight then for mica

$$d = 7.6 \times 10^{-7} \frac{pr}{t}$$

No of Ma	P.D. at Mot. terms	Current	Energy in Motor	Res. of Field	Drop in Field	Energy in Field	Energy in arm.	Res. of Arm.	Drop in Arm.	C.M. in Arm.	Effic.
1				19.25				33.0			
2	511.6	0.080	0.413	211.3	19.25	7.95	3.2	208.1	33.	13.6	5.6	2025
3	517.1	0.092	0.475	245.7	19.5	9.26	4.4	241.3	33.	15.7	7.5	23.6
4	520.6	0.160	0.825	429.5	19.75	16.3	13.5	416.0	34	23.1	23.2	33.8
5	515.6	0.179	0.9236	476.2	20.0	18.47	17.1	459.1	35	32.3	29.8	42.3
6	515.6	0.216	1.115	574.8	20.25	22.88	25.2	549.6	36	40.14	44.8	52.8
7	514.5	0.259	1.337	687.8	20.75	27.74	37.1	650.7	37	49.46	66.1	58.6
8	514.5	0.286	1.476	759.2	21.25	31.36	46.3	712.9	38	56.10	82.8	63.1
9	511.0	0.380	1.961	1002.	22.25	43.62	85.5	916.5	39	76.48	150.0	75.5
10	504.5	0.362	1.868	942.4	23.25	43.43	81.14	861.3	40.35	75.36	140.9	720.5

Test of 500-volt Motor 1/2 H.P. 16th June 92

(13)

Three inches of platinoid wire # 29 B.W.G. 0.0135" in diam. have been fixed to connect the armature with the commutator. The resistance of this wire is 0.1Ω per inch. The res: of each connection is thus 0.3Ω, and the res: coil of each armature section is 2.75Ω. Each local cct. is therefore increased by the wire in the ratio 3.35 : 2.75 = 22%.

The motor was coupled to the 120 volt machine of the same power, and the following results obtained.

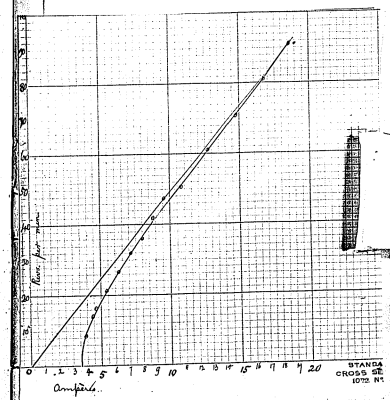
Speed R.p.s.	C.M.F. of arm.	E.M.F. per sect.	Balance	Moment	6.6 × Moment	Delivery	Friction	Commut. eff.	Speed of arm.	Total drop.
38.47	490.	12.74	50 @ 15" 200 @ 10"	2750	1.6476 × 10⁷	65.24	157.1	0.31	2208	21.55
34.33	492.1	14.33	50 @ 10 200 @ 9.0	4700	2.897 "	99.5	134.3	0.547	2060	24.96
31.0	476.2	15.37	50 @ 11 200 @ 8.0 500 @ 1.0	9650	5.95 "	184.5	203.3	0.43	1860	44.42
29.33	466.8	15.84	100 @ 6. 200 @ 5.0 500 @ 2.5	13,700	8.447 "	247.7	171.6	0.520	1760	50.77
27.33	442.9	16.20	50 @ 3.0 200 @ 2.0 500 @ 1.2	18,200	11.22 "	306.7	198.1	0.534	1640	62.72
26.0	437.3	16.82	100 @ 2.5 200 @ 1.5 1000 @ 1.0	24,175	14.90 "	387	197.6	0.563	1560	77.20
25.0	427.0	17.09	50 @ 2.2 200 @ 1.5 1000 @ 1.0	28,600	17.63 "	441	189.1	0.581	1500	87.46
23.17	391.	16.88	50 @ 2.5 200 @ 1.5 500 @ 1.0 1000 @ 0.5	40,175	24.77 "	574	182.5	0.573	1390	120.1
23.17	385.7	16.65	50 @ 2.0 200 @ 1.5 1000 @ 1.0	31,700	19.55 "	453	267.5	0.481	1390	118.8

Voltmeter Test 22nd June 1892.

The following voltmeters were standardised by Potentiometer & Clark cells:
1st Gardew voltmeter # 653 by Paterson & Cooper offering 347.5 @ 29°C
and marked as offering 329.9 @ 19°C.
2nd Weston # 1664, belonging to Lamp Test Room, offering 15,840 @ 29°C.
3rd - # 116 Direct & alternating current, belonging to Galvanometer Room
4th Howell # 214. Direct current not direct reading.

No. of Obs.	Potentiometer Observation		Howell	Diff. of Howell Correction	Weston # 1664	Diff.	Weston # 116	Diff.	Gardew	Diff.
						Correction				
1	21.8				21.8	–	21.9	0.1 –	22	0.2 –
2	25.7				25.5	0.2 +	25.2	0.5 +	25	0.7 +
3	31.25				31	0.25 +	30.75	0.5 +	31	0.25 +
4	39.8				39.2	0.6 +	39.1	0.7 +	38.1	1.7 +
5	45.95				45.9	0.05 +	45.8	0.15 +	43.8	2.15 +
6	50.85				50.0	0.85 +	50.15	0.7 +	48.1	2.75 +
7	55.45				55.1	0.35 +	55.25	0.2 +	52.6	2.85 +
8	60.45				60.5	0.45 +	60.0	0.95 +	57.2	3.25 +
9	66.1				65.5	0.6 +	65.0	1.1 +	61.8	4.3 +
10	70.15				70.0	0.15 +	69.6	0.55 +	65.5	4.65 +
11	75.7				75.0	0.7 +	74.8	0.9 +	70.5	5.2 +
12	81.05				81.0	0.05 +	81.5	0.35 –	75.5	5.55 +
13	85.15				85.0	0.15 +	84.5	0.65 +	78.9	6.25 +
14	89.65				89.3	0.35 +	89.0	0.65 +	84.	5.65 +
15	95.6				95.0	0.6 +	95.1	0.5 +	90.0	5.6 +
16	101.4		101.0	0.4 +	100.5	0.9 +	100.0	0.4 +	95.1	5.6 +
17	106.2		106.0	0.2 –	105.5	0.7 +	106.1	0.1 +	100.5	5.7 +
18	111.4		111.1	0.3 –	110.6	0.8 +	111.5	0.1 –	106.1	5.3 +
19	114.4		114.8	0.4 +	113.5	0.9 +	114.6	0.2 –	109.2	5.2 +
20	120.9		120.8	0.1 –	120.2	0.7 +	121.2	0.3 –	116.2	4.7 +
21	124.2		123.1	1.1 –	123.	1.2 +			119.	5.2 +

Fig. 3.



Tests of a new sample of zinc for Lalande cells.

A new brand of zinc from Pennsylvania is under trial. The first quality sold for 7½ d per lb. is said to be almost chemically pure. The second quality sold for 6½ . . . . . 99% pure. The made up with the 100% and five more with the 99% zincs. Twenty five plates in all. The cells were set up on the 23rd June.

100 %

No. of plate	Weight 23rd June	Weight 14th July	Weight 30th Aug.
1	271·0	267 4	248 17
2	256·5	250 6·5	230 20
3	290·0	287 3	270·5 19·5
4	253·0	250 3	240·5 9·5
5	280·5	279 1·5	272 7
6	250·5	247 1·5	243 4
7	255·0	254 1·0	248 6
8	293·0	292 1·5	285 7
9	251·0	248 3	243·5 4·5
10	266·5	264 2·5	257 6·5
	2667·5	2640 27·5	2537·5 102·5
		27·5 per plate	13·5 per plate

99 %

No. of plate	Weight 23rd June	Weight 14th July	Weight 30th Aug.
11	303·5	301 2·5	296 5
12	299·0	297 2·0	292 5
13	319·0	316 3·	304 12
14	308·0	305 3·	291 14
15	308·5	306 2·5	301 5
16	301·5	297 2·5	294 3
17	291·5	289 2·5	282 7
18	288·5	286 2·5	279 7
19	291·0	289 2·	281 8
20	322·5	320 2·5	313 7
	3013·0	3005 25	2933 80
		25 per plate	4 per plate

Diminution of Zinc. 100% 17·4 over all, 11·1 from shoulder. 99% - - 7·75 from shoulder.

0·442 thick
0·508 .

Cells left on open circuit

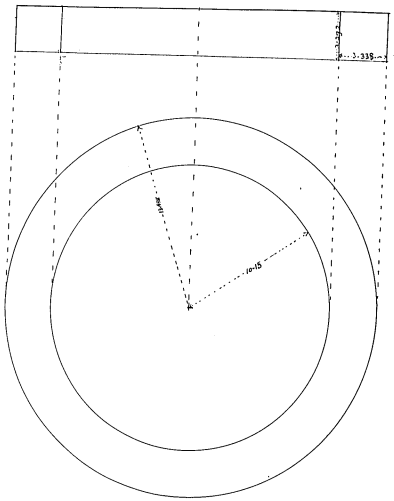
Test of alternating-current motor for patent case.

27th June.

The first test on p. 76 showed that the iron blades were not large enough. They were now increased to aluminium plates 13·25 square whose centres are in the same plane 24·3 distant. The following results were then obtained

No. of obs	Ohms	Amps	Lamps	Rpm.	R.p.m. per amp.	R.p.m. per ohm.	R.p.m. per amp per ohm
1	0·744	3·839	9	8·5	2·214	0·142	
2	0·833	4·299	10	14·0	3·257	0·233	
3	0·885	4·566	11	16·2	3·548	0·27	
4	1·041	5·372	13	21·3	3·965	0·355	
5	1·212	6·253	15	26·7	4·269	0·445	
6	1·370	7·070	17	32	4·526	0·533	
7	1·545	7·972	19	36	4·516	0·6	
8	1·710	8·824	21	42	4·760	0·7	
9	1·855	9·570	23	47·5	4·963 ?	0·779	
10	2·077	10·720	25	50·5	4·712	0·842	
11	2·467	12·730	30	61	4·792	1·017	
12	2·860	14·760	35	71	4·811	1·193	
13	3·230	16·670	40	81	4·859	1·35	
14	3·60	18·58	45	91	4·899	1·517	

Plan and Diametral Section of Ring #1. – Submitted to our committee

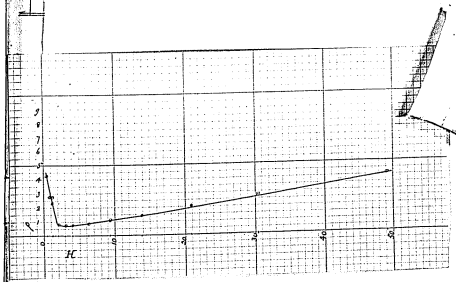


External	Radius	13.488	Diameter	26.976	Circumference	84.76	Red^{n} 181.9
Internal	"	10.15	"	20.3	"	63.78	" 103.02
Mean	"	11.819	"	23.638	"	74.26	" 78.88

Mean	Radial depth	3.338
"	height	2.292
"	Gross section	10.99 cm^{2}
	Plane area	247.8 "
	Volume by measurement	816.0
	Mass observed	7684.9
	Sp. gravity	6.906
Primary	winding	183 turns
Secondary	"	50 "

$\frac{183}{74.26} = 2.464 \times \frac{4\pi}{10} = 3.097.$

	Obsd
1	0.038
2	0.085
3	0.07
4	0.121
5	0.18
6	0.2
7	0.3
8	0.5
9	0.9
10	1.2
11	1
12	3
13	5



Test of Malleable Iron Samples from Trenton N.J.

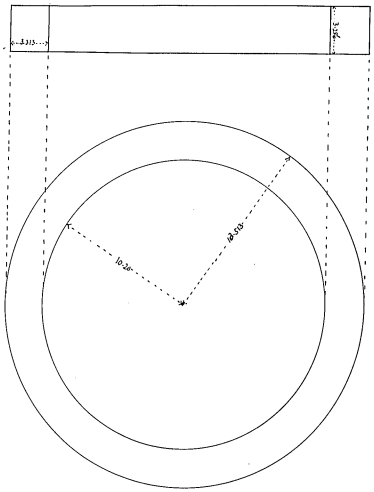
24th June.

	Source of EMF	EMF at temp.	Capacity	q.	Mean Value	q. per div.
	1.86 @ 25.6° C.	1.426×10^{8}	1×10^{-15}	1.426×10^{-7}	150.8	9.454×10^{-10}

No. of Obs.	Obsvd.	Amp.	H	No. of Times	Mean Value	q.	Log. Gain per cent.	Total Gain of Q. per cent.	10^4 Q.	B	μ	ρ
1	0.0321	0.160	0.4954	4	35.5	2.411×10^{8}	0	5350	12,900	1174		4.22×10^{-4}
2	0.02565	0.2915	0.9026	4	64.75	6574 "	0	"	35,280	3241		2.811 "
3	0.0735	0.3792	1.174	3	110	1044 "	0	"	55,640	5063		2.319 "
4	0.1255	0.6475	2.005	4	171.4	16.21 "	10,000	15,350	248,800	22647		0.8856 "
5	0.1825	0.9415	2.916	4	253.1	11.47 "	25,000	30,350	439,200	39976		0.7298 "
6	0.2525	1.303	4.035	3	206.	19.48 "	"	"	591,300	53810		0.7520
7	0.3885	2.004	6.206	4	151.5	11.33 "	50,000	55,350	793,200	72,218		0.8578
8	0.5775	2.980	9.228	4	177.5	16.78 "	"	"	929,800	84,621		1.092
9	0.863	4.453	13.790	4	198	18.72 "	"	"	1,036,000	94,276		1.463
10	1.305	6.734	20.85	4	217.5	20.56 "	"	"	1,135,000	103,360		2.013
11	1.90	9.804	30.36	4	236.25	22.34 "	"	"	1,237,000	112,600		2.696
12	3.070	15.84	49.05	4	251.5	23.78 "	"	"	1,316,000	119,800		4.094
13	5.700	29.416	91.08	4	278.75	26.36 "	"	"	1,459,000	132,800		6.860

[illegible]
[illegible] 181.9
[illegible] 103.02

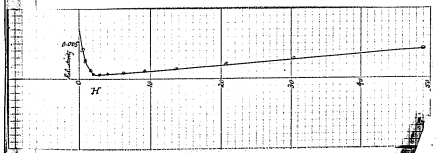
Plan and Diametral section of Ring # 2.



External	Radius	13.513	Diameter	27.026	Circumference	84.92	Rad^s 182.5
Internal	-	10.20	-	20.40	-	64.09	10 do as
Mean	-	11.857	-	23.713	-	74.51	78.56

Mean radial depth	3.313
Mean Height	3.286
Cross-section	10.886 cm^2
Plane area	~~246.5~~ "
Volume by measurements	~~36.6~~ 9 10.54 c.c.
Observed mass	5684.0 gms.
Sp. g. by measurement	6g60 7.0114
Primary winding	183 turns
Secondary winding	50 -

$\frac{H}{\gamma} = \frac{183}{74.51} \times 1.2566 = 3.086$

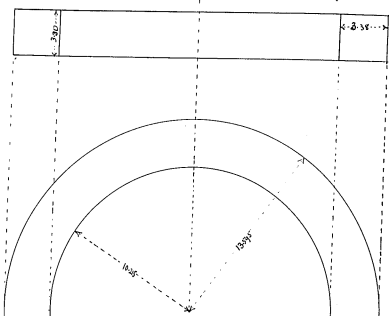


Test of Malleable Iron & sample from Trenton contd.

Thick Wire	Wt. in air	Wt. in amp.	H	No. of Turns	Mean Turns	q	Rec. reluct. in q. cc.	Total Rec. in q. cc.	q	B	μ	ρ
1	0.031	0.160	0.494	3	25.75	2.453×10^{-3}	0	53.50	1312	120.5		$4 \cdot 10 \times 10^{-3}$
2	0.0565	0.2415	0.900	3	73.75	6.972	0	"	3,730	342.6		2.627
3	0.0735	0.3792	1.170	3	128.5	1.404×10^{-2}	0	"	7,510	689.8		1.696
4	0.1255	0.6475	1.998	3	229	2.165	19,250	15,350	33,230	3052		0.6046
5	0.1825	0.9415	2.905	3	176.7	1.672	25,000	30,350	58,740	4661		0.6238
6	0.2525	1.303	4.021	3	224.7	2.124	"	"	64,470	5922		0.679
7	0.3885	2.004	6.185	4	150.6	1.424	50,000	50,350	78,820	7240		0.8522
8	0.5775	2.980	9.198	4	173	1.636	"	"	90,550	8318		1.106
9	0.863	4.453	13.74	4	195	1.843	"	"	102,000	9370		1.467
10	1.305	6.734	20.78	4	210.6	1.991	"	"	110,200	10,120		2.053
11	1.90	9.804	30.25	4	220.8	2.087	"	"	115,500	10,610		2.851
12	3.070	15.84	48.89	4	242.3	2.291	"	"	126,800	11,650		4.196
13	5.700	29.416	90.78	4	266.5	2.520	"	"	139,500	12,810		7.088

Source of EMF	EMF at temp	Reluctivity	q.	Mean Throw	q. per div.
16 volts @ 15.6°C.	1.4226×10^{8}	1×10^{-15}	1.4226×10^{-7}	156.8	9.1254×10^{-10}

Plan and Diametral Section of Ring # III (Was undergone three annealings)

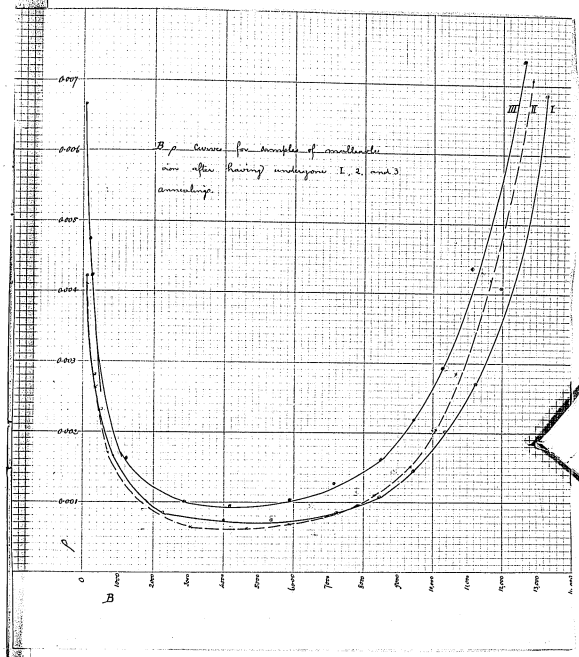


External Radius	13.595	Diameter	27.19	Circumference	85.42
Internal "	10.215	"	20.43	"	64.19
Mean	11.905	"	23.81	"	74.80

Rad^{us} 184.82 − 104.34 = 80.48

Mean radial depth	3.380 c.
Mean height	3.30
Cross section	11.154 c.c.
Plane area	252.8 c.c.
Volume by measurement	834.4 c.c.
Observed Mass	5684 g.
Sp. g. by measurements	6.812
Primary winding	183 turns
Secondary "	50 "

$$\frac{H}{\gamma} = \frac{183}{74.8} \times 1.2566 = 3.075$$



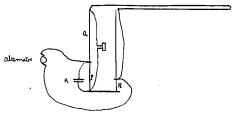
B ρ curves for samples of annulus cut from Ring # III undergone I, 2, and 3 annealings.

Plan . . a.

Test of Sample of Malleable Iron from Trenton N.J.

Set No.	Obsd.	Amp.	H	No. of Rdgs.	Mean Rdgs.	q	Res. reads Lo g. ect.	Res. of g. ect.	F	B	r	ρ
1	0.031	0.160	0.492	3	16.3	1.574×10^{-5}	0	5350	8243	73.9		6.66×10^{-3}
2	0.0565	0.2915	0.896	3	41.8	3.452	0	"	2,114	189.6		4.726 "
3	0.0735	0.3792	1.166	3	60.9	5.748	0	"	3,075	275.7		4.229 "
4	0.1255	0.6475	1991	4	94.75	8.957	10,000	15,350	13,150	1233.0		1.615 "
5	0.1825	0.9415	2.895	4	111.5	1.054×10^{-4}	25,000	20,350	31,990	2868.		1.010 "
6	0.2525	1.303	4.006	3	162.7	1.538 "	"	"	46,680	4195.		0.957 "
7	0.3885	2.004	6.162	4	126.2	1.193 "	30,000	55,350	66,040	5922		1.041 "
8	0.5775	2.980	9.164	4	153	1.446 "	"	"	80,040	7176		1.288 "
9	0.863	4.453	13.69	4	180.75	1.709 "	"	"	94,600	8482		1.611 "
10	1.305	6.734	20.71	4	201	1.90 "	"	"	105,200	9430		2.197 "
11	1.900	9.804	30.14	4	219	2.07 "	"	"	114,600	10,275		2.934 "
12	3.070	15.84	48.71	4	237.2	2.242 "	"	"	124,100	11,130		4.377 "
13	5.700	29.416	90.43	4	262.5	2.472 "	"	"	137,400	12,320		7.342 "

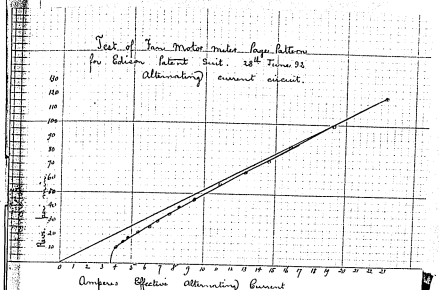
	Source of EMF	EMF at temp	Capacity	q	Mean Rdgs	q per div
	16 cells @ 25.6°c	1.426×10^{8}	10^{-15}	1.426×10^{7}	150.8	0.9454×10^{-3}



$\lambda = 4 \log_{\frac{1}{2}} \frac{1}{7} = 4 \log_{\frac{1}{2}} \frac{4.5}{0.036} = 4 \log_{\frac{1}{2}} 125.5 = 4 \cdot 2104 \times 2 \times 1248 = 19.87 + 1 = 20.87$

$20.87 \times 1380 = 28,806$

Test of Iron Motor under Page Patent
for Edison Patent Suit. 28th June 92
Alternating current circuit.



Test of Alternating Current Motor Meter 28th June 92.

The instrument after having been tested on continuous currents, was operated by alternating current transformer, using 100 volts in the secondary, through Siemens Dynamometer and Lamp-Bank.

No	Degrees	$\sqrt{8}$	Amperes	Revs per min	Revs per sec	Ohms per rev	Rate per day	Observed Drop λ
1	19°	4·359	3·998	11	0·183	2·758		10
2	23·5°	4·848	4·1436	15	0·25	3·381		11
3	26·5°	5·148	4·710	18	0·3	3·822		12
4	36°	6·0	5·189	21·75	0·363	3·962		14
5	46°	6·782	6·205	26·3	0·438	4·239		16
6	55°	7·416	6·786	30	0·5	4·421		18
7	64°	8·307	7·60	35	0·583	4·605		20
8	83°	9·110	8·336	40	0·6	4·797		22
9	105°	10·247	9·377	45·5	0·758	4·853		25
10	114·5°	12·185	11·15	56	0·93	5·023		30
11	200°	14·142	12·94	65	1·083	5·023		35
12	253°	15·906	14·55	73	1·218	5·018		40
13	311°	17·635	16·135	83	1·383	5·145		45
14	40°	6·325	19·07	99·5	1·658	5·218		55
15	55°	7·416	22·36	119	1·983	5·322		67
16	54°	7·348						2·6 volts

Res. of instrument warm 0.139 ω.

Measurement of Inductance June 29th

A metre bridge was arranged for the measurement of small inductance. The wire was 100 cms. long on the bridge scale and also 100 cms. long on the comparison scale, it was of platinoid, and had a diameter of 0.018. Its resistance is 0·149·17 ω per cm. 0·14372 Tum ohm. Balance was first obtained with a battery, and then the battery was replaced by the unexcited alternator, giving some 1140 ~ per second. The insertion of a condenser with a very slight readjustment of the bridge restored silence in the telephone.

A loop of soft copper wire was stretched along the floor. The length of each side, 1380, the diameter of the wire 0·072, and the distance 4·8 between axes.

P = 42·35 R = 6·9 ∴ P = 6·087 ω R = 49·918 ω
Q = 47·65 K = 3·365 Q = 6·85 ω

$\rho = \frac{QR}{P}$ = 1·116 ω.
$l = \rho K P$ = 1·116 × 6·087 × 3·365 = 22·86 microhenrys

Calculated inductance 28·4 microhenrys. The condenser & resistor & 0·01

Repetition of test after making several improvements in connections.

P = 54·73 R = 10·15 P = 7·865 R = 4·458
Q = 45·27 K = 3·13 Q = 6·506

$\rho = \frac{QR}{P}$ = 1·206 ω
$l = \rho K P$ = 1·206 × 7·865 × 3·130 = 29·7 microhenrys.

520·57

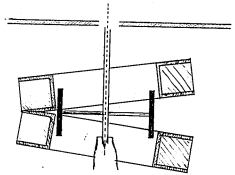
Physiological Experiments 8th July 92.

Dr Frederick Peterson prepared a slide with some freshly collected ciliated epithelium from the throat of a freshly slain frog. This slide was examined under a microscope when placed in a horizontal position between the conical pole of the large electromagnet, the airgap being about 1 cm. Exciting or relaxing the magnet had no apparent effect on the movements of the cells. Blood was next tried with no better success.

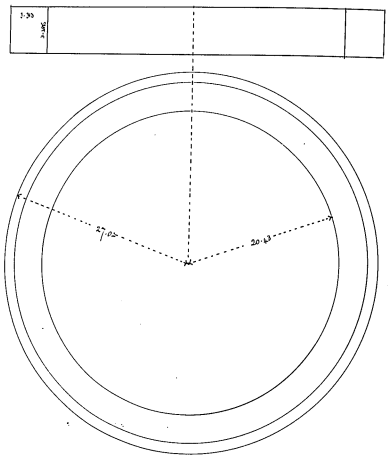
The web in the foot of a living frog was next tried, the web was extended in the horizontal plane with the poles about 1·5 apart. The circulation was clearly visible, but no magnetic effects could be observed.

On attaching one wire to a toe, and the another to the foot above the ankle, so as to pass a current through the limb under examination, and after curare had been administered (injected) subcutaneously to stop the muscular twitch on making and breaking contact, it was observed by Dr Peterson that a current of one milliampere through the foot would arrest circulation. There would be a movement any stimulus on at closing the circuit, followed by an abatement of activity, until within about ten seconds the circulation would have stopped in most of the vessels. On breaking the circuit the circulation would slowly reestablish, until in about ten seconds the flow with apparently normal rapidity. This observation was repeated several times.

A brown terrier dog was chloroformed, and experiments made with an induction coil worked by battery to ascertain if any motor areas in the brain could be stimulated through the skull by using needles close together. No success could be obtained, although superficial nerves and muscles could be stimulated. It would appear that the highly vascular nature of scalp and skull short circuited the stimuli and prevented the current from the needles reaching down into the brain substance. Even when the skull was broken, and the needle let down through the incision no effect was visible, the blood apparently short circuiting.



Plan and Diametral Section of Ring #1 w.



External	Diameter	27.02	Radius	13.51	Circumference	84.9	Rad.ⁿ 182.5
Internal	-	20.43		10.215	-	64.18	- 104.39
Mean	-	23.725		11.863	-	74.54	78.16

Mean	Radial depth	3.313
-	height	3.286.
-	cross section	10.89
-	Plane area	245.6
-	Volume by dimensions	807
Observed	mass	5641
	Sp g by dimensions	6.99.
Primary	winding	183 turns
Secondary	-	50

$\frac{H}{\gamma} = \frac{183}{74.54} \times 1 = 2566 \quad = 3.086.$

Test of sample Malleable Iron Rings.

(21)

		No 1	No 3.	No 4	No 5.	No 2 w	No 3 w.
External	Radius	13.91	13.75	13.618	13.587	13.582	13.563
-	Diameter	27.82	27.49	27.235	27.173	27.163	27.125
-	Circumference	87.38	86.4	85.5	85.4	85.4	85.2
Internal	Radius	10.39	10.26	10.208	10.264	10.194	10.163
-	Diameter	20.78	20.51	20.415	20.527	20.387	20.325
-	Circumference	65.28	64.4	64.1	64.5	64.0	63.8
Mean	Circumference	76.33	75.4	74.8	74.95	74.7	74.5
Mean	Radial depth (R-r)	3.524	3.488	3.410	3.323	3.388	3.~~400~~
-	Height	2.945	3.121	3.320	3.310	3.270	3.280
-	Cross section	10.38	10.89	11.32	11.0	~~12~~.08	11.56.
-	Plane area	267.2					
-	Volume by dimensions	792.2	821.0	845.2	824.4	827.6	861.2
Observed	mass	5443 12 Dec.	5698 12 Dec 90.	5~~7~~854 12 Dec 05	5882 12 Dec 80	5~~6~~81 12 Dec. 70	5726 12 Dec. 100
Mean	Sp g. by dimensions	6.87	6.94	6.81	7.135	6.814	6.65
Primary	winding	183	183	183	183	183	183
Secondary	winding	49	50	50	50	50	51
H/γ		3.013.	3.05	3.075	3.068	3.079	3.~~05~~8

Ring #2 whose test appears on page 87, was broken up to examine the iron in the interior. It proved to be in fairly good condition throughout.

Ring #3 was heated in the forge and hammered by hand. Its height was thus reduced from 3.30 to 3.12, the radial width being increased from 3.38 to 3.41 by the same operation. The mass was 5684 before and 5698 after.

Ring #1 was heated in the forge and compressed by drop hammer. Its height was reduced from 3.29 to 2.945, and its radial breadth increased from 3.34 to 3.52. The mass was reduced from 5635 to 5443 but the apparent sp g. underwent very little change.

Ring # 1

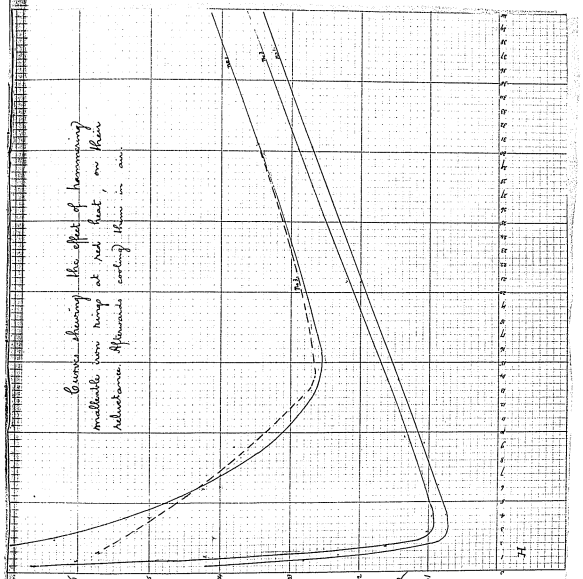
No. of Obs	Obsvd.	Amps.	H	Lbs added to C. at	Dist of Cylinders		H	Mean Thmr.	q $\times 10^{-8}$	F	B	ρ $\times 10^{-3}$
1	0·024	0·1238		0	5300	5400 5196	13·73	9·75	0·892	1482	146·4	8·038
2	0·0542	0·2797		0	"		8·427	23·3	2·131	1,152	111·0	7·392
3	0·0644	0·3424		0	"		1·032	26	2·378	1285	123·8	8·336
4	0·0964	0·4974		10,000	15300	15400 15,000	1·498	13	1·189	1954	178·7	8·383
5	0·1574	0·8122		"	"		2·448	28·1	2·57	4·009	386·2	6·339
6	0·2423	1·250		25,000	30,300	30900 29,900	3·766	24·8	2·268	1,737	706·8	5·329
7	0·3621	1·869		"	"		5·631	46·5	4·253	1,740	1267	4·444
8	0·5457	2·817		50,000	55,300	56,400 54,220	8·457	45·1	4·125	2,260	2241	3·787
9	0·816	4·211		50,000	"		12·68	96·3	8·809	49,680	4786	2·649
10	1·263	6·52		50,000	"		19·64	142·3	13·02	73,420	7074	2·777
11	1·916	9·888		50,000	"		29·79	175	16·01	90,300	8699	3·425
12	3·087	15·92		50,000	"		48·0	205	18·75	105,750	10,185	4·713

Ring # 2 ~ 51

No. of Obs	H	Mean Thmr	q $\times 10^{-8}$	F	B	ρ
1	0·38	37·1	3·393	1763	152·5	2·492
2	0·86	107·5	9·834	5110	442	1·946
3	1·06	142	12·99	6750	583·9	1·815
4	1·514	134·4	12·29	18,450	1594	0·966
5	2·51	346·4	31·50	47,250	4087	0·615
6	4·05	208	19·02	58480	4886	0·829
7	6·06	280·8	25·69	76,300	6600	0·918
8	9·13	179	16·37	81,750	7677	1·189
9	13·00	201·8	18·46	100,100	8660	1·501
10	20·12	224·5	20·99	113,800	9844	2·022
11	30·5	259·5	22·91	124,200	10,740	2·840
12	49·3	268·3	24·54	133,050	11,510	4·275

Ring #3

H	Mean Thmr	q $\times 10^{-8}$	F	B	ρ
0·38	11·5	1·052	557·3	51·18	7·425
0·86	31·8	2·909	1542	141·6	6·074
1·06	31·8	2·909	1542	141·6	7·488
1·64	21	1·921	2939	269·9	5·705
2·51	47	4·249	6878	604	4·155
4·05	31·8	2·909	88134	809·4	5·082
6·06	56	5·122	15,820	1425	4·253
9·13	58·8	5·198	28,740	2639	3·146
13·00	102·3	9·358	51,750	4752	2·736
20·12	151·5	13·86	76,640	7038	2·859
30·5	187·5	17·15	94,930	8710	3·501
49·2	221·0	20·21	111,600	10,250	4·80



Collection of Tests on seven malleable Iron Rings.

Ring #1.

H	Mean Thick	q ×10⁻⁶	F	B	ρ
0.382	1.5.3	4.1141	2,196	201.6	1.895
0.963	12.56	9.660	5,120	470.1	1.836
1.057	16.4.3	15.03	7966	731.6	1.1445
1.535	16.7.5	15.32	23,440	2152.	0.7132
2.507	34.7.	31.74	48,560	4459	0.562
4.051	21.2.	19.39	58,750	5395	0.751
6.056	26.3.	24.06	72,900	6694	0.905
9.128	16.2.5	14.86	88,170	8096	1.128
12.99	18.3.	16.74	92,570	8501	1.528
20.12	22.0.8	20.20	111,700	10,260	1.961
30.51	23.3.3	20.143	113,000	10380	2.937
49.16	24.6.	22.50	124,400	11420	4.304

Ring #2.

H	Mean Thick	q ×10⁻⁶	F	B	ρ
0.38.	40.2	3.677	1949	175.9	2.160
0.86	123.5.	11.3	5989	5140.5	1.591
1.06	182.3	16.67	8835	797.4	1.329
1.524	176.5.	16.14	24,700	2229	0.691
2.51	338.8	30.98	47,400	4278	0.587
4.05	201.4.	18.66	56,540	5102	0.794
6.06	253.5.	23.19	70,260	6341	0.956
9.13	164.5.	15.05	83,220	7510	1.216
13.99	186.8	17.09	94,500	8528	1.525
20.12	212.	19.39	107,200	9674	2.080
30.5	226.3	20.7	114,500	10,320	2.952
49.2	237.	21.68	119,900	10,820	4.526

Square of Emf	Emf at temp	Capacity	q.	Mean Thick	q. per turn	No. of Turns
1. C.C. 20	1.4295	1	1.4295×10⁻⁷	156.3	q.148×10⁻¹⁰	8

Ring #4.

H	Mean Thick	q ×10⁻⁶	F	B	ρ
0.38					
0.86					
1.06					
1.52.	142.0	12.99	19880	1756	0.877
2.51	342.6	31.23	47,780	4220	0.595
4.05	220.2	20.14	61,620	5390	0.751
6.06	264.3	24.18	73,260	6472	0.937
9.13	175.0	16.01	88,530	7821	1.168
13.00	200.0	18.29	101,140	8934	1.455
20.12	223.0	20.4	112,800	9964	2.019
30.5	231.5	21.18	117,100	10,345	2.948
49.2	255.2	23.33	129,000	11,395	4.318

Ring #5.

H	Mean Thick	q ×10⁻⁶	F	B	ρ
0.38					
0.86					
1.06					
1.524	128	11.71	17,920	1629	0.945
2.51	306.8	28.06	42,920	3903	0.643
4.05	198.5	18.16	55,020	5002	0.810
6.06	252	23.05	69,840	6349	0.954
9.13	164.8	15.08	83,380	7580	1.204
13.00	191.8	17.54	97,000	8820	1.474
20.12	209.5	18.61	102,900	9355	2.157
30.5	237.5	21.72	120,100	10,827	2.817
49.2	242.	22.23	122,900	11,175	4.402

Test of an Ernst Storage Cell July. 8th 92.

This arrangement of plates in this cell forms a mass 15·9 x 17.2 with. There are 13 horizontal plates, 7 + and 6 interleaved —. The flat surfaces of each side of 275 sq. cms., and the active (flat) surfaces on each whole plate or electrode = 3300 sq. cms. The weight of all 13 plates and their frames dry = 46·5 lbs = 21·1 Kilos. Each plate averages with attachment 3·6 lbs. or 1·6 kilos. The total weight of the cell is 35·1 Kilos or 77 lbs with 7000 c.c. of dilute H_2SO_4 of density 1.17 @ 20°C.

The cell was set up on the 7th July, and tested on the 8th. Its EMF was then 1·6 volt. It was discharged through 1 ω for four hours when the pd. was 0·6 volt. It was then charged from the 100 volt circuit through a lamp bank.

Date	Time	Hrs. Mins	Total Hrs.	Current by Potents	Means.	Amp. Hrs.
July 8th	14·40			5·42		
"	18·00	3·15		5·88	5·65	17·8
" 9th	8·40			5·60		
"	13·0	4·20	7·35	5·86	5·73	24·1
" 10th	8·10			4·31		
" "	12·0	3·50	11·25	4·60	4·46	15·6
" "	12·20			4·50		
" "	18·00	5·20	16·45		4	
" 12th	9·0			4·97		
" "	12·0	3·0	19·45	5·0	5·0	
" 11	13·0			-		
" "	18·0	5·0	24·45	5·95		
" 13th	9·0			6·0	6·0	
" "	12·0	3·0		-		

July 14th Discharged cell direct through large meter 0·376 ω @ about 6 amp

Weight of zinc plate

Before	44·220	47·260	
after	44·185	47·205	
	·035	·045	Mean 0·040 X 1·1228 = 44912

Result 45 amp. hr

July 15th Charged cell through meter at 10 amp. P.D. 1 volt on 0·1 ω

Before	46·695	42·810
	46·505	42·880
	·090	·070	Mean 0·080 X 1·1228 = 89.824

July 16th Discharged cell through meter direct about 6 amp

Before	45·220	47·155
	45·175	47·207
	·045	·052	Mean 0·0485 X 1·1228 = 54.45

July 18th Charged cell @ 5 amp but charger missed.

July 21st Discharged cell Before 41·570 47·250 thro meter

after 41·855 47·280

·015 ·020 Mean 0·0175 X 1·1228 = 19.65

July 22nd Charged cell @ 6 amp

	43·517	44·790	46·185	44·250	
After	43·870	44·740	46·235	44·200	
	·033	·050	·050	·050	Mean 0·051 X 1·1228 = 57.2

23rd Discharged Before 43·355 43·835 45·585 42·910

after 43·325 43·865 45·550 42·940

·030 ·030 ·030 ·030 Mean 0·030 X 1·1228 = 33.7

Loss in feeder #1 $\frac{1187}{1064.5} \quad \frac{122.5}{1187} = 10.32\%$ in feeder #1

" " conn: cct #1 $\frac{1064.5}{1023.} \quad \frac{41.5}{1064.5} = 3.9\%$ " mains

" " feeder #2 $\frac{1219}{1152} \quad \frac{67}{1219} = 5.5\%$ " feeder #2

" " conn cct #2 $\frac{1152}{1080} \quad \frac{72}{1152} = 6.67\%$ " mains #2.

Alternating Current Primary Pressures measured in Newark N.J. by Mr Hammer. 2nd July 92.

End of Feeder #1 20.145 vol: Leg. Dept. voltmeter + 500 ω res: connected to neutral and negative terminals of 80 lt 4 KW transformer from Laboratory 103 volts @ 75°F Ratio of this transformer = 500 : 50 = $\frac{25}{2}$ Res: of voltmeter # 238 2083 ω $(2083 + 500)/2083 = 1.240 \times 8.3 = 10.335$ multiplier $103 \times 10.335 = \underline{1064.6}$ volts.

B.S. bus bars at 20.145 vol. Laboratory voltmeter, + 20,000 ω 111 volts @ 75°F Res: of 20,000 ω = 19,978 Res. of voltmeter # 116 = 2060 ω @ 80°F.

$\frac{19,978}{2060} = 9.698 + 1 = 10.698$ multiplier. $10.698 \times 111 = \underline{1187}$

Far end of consumption circuit fed by #1 21.10 vol. Leg. Dept. Voltr: 99 @ 75°F

$99 \times 10.335 = \underline{1023}$

B.S. bus bars as before 111 @ 75°F = $\underline{1187}$.

Far end of consumption circuit fed by #2. 22 vol. Legal Dept. voltr:

104.5 volts @ 72.5°F $104.5 \times 10.335 = \underline{1080}$

B.S. bus bars at the same time Lab. voltr $114 @ 83°F = \underline{1219}$

End of Feeder No. 2. 22.20 vol:

Legal Dept. voltr: 111.5 @ 72.5°F = $\underline{1152}$ volts.

B.S. bus at same time. Lab. voltmeter 115 volts @ 83°F $115 \times 10.698 = 1230$.

Secondary tests

	No 1.		No 2.	
End of feeder	50 volts @ 9.50 pm:	(c.s. bus 114)	53 v: @ 10.25 pm:	(c.s. bus = 116)
Half way on Conn Cct 48	" " 9.40	(c.s. " 112)	52 "	10.20 " (c.s. " = 115)
End of conn: cct 147	" 9.20	(c.s. " 111)	52 "	10.05 " (c.s. " = 114)

No 2.

Tests taken on the 3rd July.

24,002 ω total res: of cct (11,977 + 9965 + 2060 ω) including # 116 = multiplying power $\frac{24,202}{2060}$, 11.65. Electrician pr. d. 1270.

Measurement of Inductance in Ohm.

A straight length of wooden moulding with a groove 1.3 cms wide was selected, about 4.25 cms long. A galvanised iron wire 0.158 (0.062 # 14 B.W.G.) such as is used in telephone work, was doubled, and the loop fixed in this groove. the sides being pressed against the wall of the groove by copper tacks. The arms of the wires were then separated by a distance of 1.142 cms.

The resistance of the loop by bridge 1000 ~ was 0.612 ω. with Galvr. With the unexcited alternator as E.M.F. and a telephone in place of Galvr the balance was 1000 ~ 0.631 ω = 0.130 %. This balance silenced the principal note, but there appeared to be higher residual notes that & no adjustment was found to suppress.

$0.631 \times 1000 \times 0.130 = 8203$ microhms = 82030 cms = 192.2 cms for one of loop.

By Theory $\frac{b}{r} = 4 \log_e \frac{b}{r} + \mu$

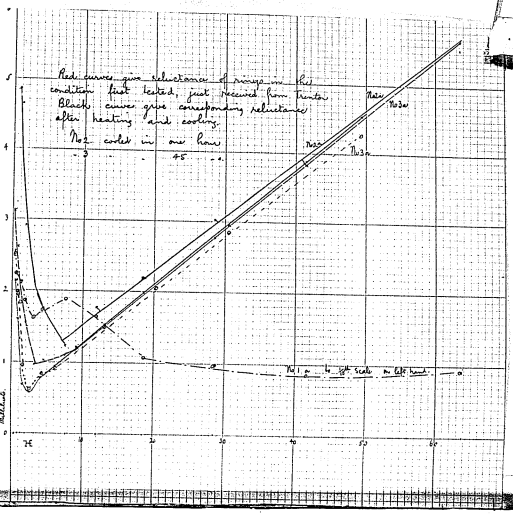
$192.2 - 10.68 + \mu$

$\mu = 181.52$

In this case $b = 1.142$ $r = 0.079$

$\frac{b}{r} = 14.45$ $\log_e 14.45 = 1.16017 \times 2.3026 = 2.67$

$2.67 \times 4 = 10.68$


Red curves give resistances of wires as they
condition first tested, just received from Trenton.
Black curves give corresponding resistances
after heating and cooling.
No 2 cooled in one hour
No 1 on 4th scale
No 2
No 3
No 2a
No 3a
Ohms
Hours

Experiments on the annealing of malleable iron rings.

In 2a and 3a of pages 91 & 92 were stripped of wire, taken to the forge & heated to a full red heat. No 1a was promptly chilled by plunging in water. It had nearly reached the temperature of the surrounding air in one minute. No 2a was allowed to cool on ashes in a pan. It was cool in about one hour. No 3a was allowed to cool in ashes & slowly extinguishing bonfire, & was cool in about 45 hours. The three rings were then reannealed and tested. They were 50 hours in each secondary and 176 in each primary.

No of Exp	EMF at beg	Capacity	q.	Mean throw	No of throws	q per div	Mean
1a	1.4236×10^{1}	$10^{-9.5}$	1.4236×10^{-7}	149.2	11	9.9522×10^{-9}	
2a & 3a	1.4247		1.4247 -	148.9	7	9.9566 -	9.9549×10^{-9}

	$\frac{1}{R}$	$\frac{1}{R+r}$	$\frac{r}{R}$	$\frac{r}{R+r}$	$\frac{1}{n}$	$\frac{n}{R}$	$\frac{n}{R+r}$	$\frac{1}{n^2}$	$\frac{1}{n^2 R}$	$\frac{1}{n^2(R+r)}$	$\frac{r}{n^2 R}$	$\frac{r}{n^2(R+r)}$
1a	0.1023	0.1023	0	0	0.0227	0.2327	0.2327	0.0005	0.0052	0.0052	0	0
2a	0.2439	0.2439	0	0	0.0441	0.5041	0.5041	0.0019	0.0465	0.0465	0	0
3a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
4a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
5a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
6a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
7a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
8a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
9a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
10a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
11a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
12a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
13a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
14a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
15a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
16a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
17a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
18a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
19a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
20a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
21a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
22a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
23a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
24a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
25a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
26a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
27a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
28a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
29a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
30a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
31a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
32a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
33a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
34a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
35a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
36a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
37a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
38a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
39a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
40a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
41a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
42a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
43a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
44a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
45a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
46a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
47a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
48a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
49a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0
50a	0.4102	0.4102	0	0	0.0577	0.8577	0.8577	0.0033	0.0977	0.0977	0	0

Mean ci: 74.7

$\frac{176 \times 1.2567}{74.7} = 2.961$

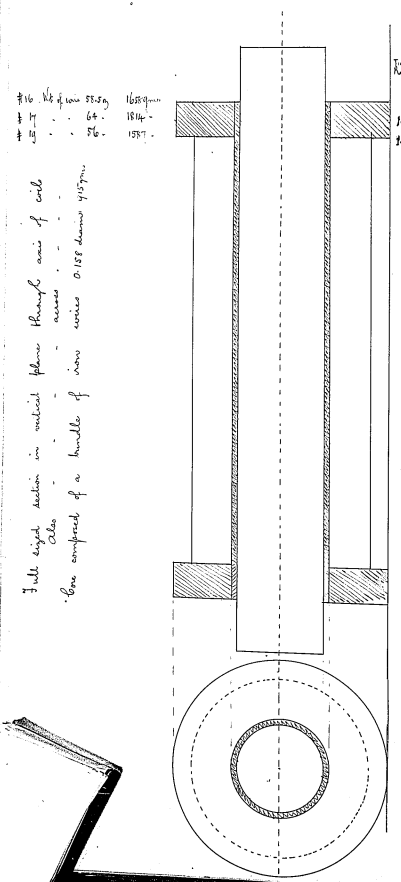
When these rings are suspended by a cord in the a vertical plane & struck gently in their own plane, about the midway.

The engines the mots are

1a - - - 3.85×10^{-5} ergs

2a - - - 3.85×10^{-5} ergs

3a - - - 10.240×10^{-5} ergs


#16 No of turns 58.5 1658 cm
17 - - 64 - 1814 -
19 - - 56 - 1587 -
Full sized section in vertical plane through axis of coil
Also - - - - - -
One completed of a bundle of iron wires 0.158 diameter 4.57 cm.

Turns Units

1 Coil #16, 9 layers 101 turns 916
3.88 - # 17, 11 - 114 - 1254
3.825 - # 19, 12 - 139 - 1063

Measurements of Inductance. July 10th 1914

(96)

No.	Obs	No. of Coil	Res. obs	Leads or Insertion	Res. of coil	Bridge	Condenser	Inductance millihenrys	Stand. correct.	Turns Const.	Ind. inserted	Ind. of coil
1		Mains	5.955	0.026	5.929	1000/10	4.405	26.23				
2			8.641	Exhibit #6		-	3.535	30.55	0.140			
3			122.15	" + 100		1000/100	0.258	31.51	0.013		0.8	30.7
4		Core inserted	122.85	"		"	3.093	377.75	"		"	377
5			92.	" + 30		"	4.118	378.9	0.015			378.
6			91.99	"		-	4.268	392.6	0.038			391.8
7			82.0	"		-	4.808	394.2	0.047			393.4
8		Exhibit #6	153.56	0.086	153.47	"	0.593	91.04				
9		" #6	14.926	"	14.84	-	0.055	0.82				
10		"	14.91	"	14.95	100/10	0.550	8.82				
11		" #6	1.559	"	1.4604	"	0.10	0.0152				
12		"	1.557	"	1.471	1000/10	0.01	0.0152				
13		Coil #17	5.192	1.562	3.630	1000/10	3.475	18.014	0.047		0.015	17.925
14			7.187	3.562	3.625	"	2.50	17.975	"		"	17.960
15			3.718	0.086	3.632	"	1.85	17.62			0	
16		Core inserted	118.56	Exhibit #6	103.6	1000/100	1.83	21.70	0.013		0.82	20.62
17			118.56	"	"	"	1.97	22.17	0.044		"	22.09
18			105.16	" #6	"	"	2.105	22.14	0.05		0.02	22.12
19		Coil #16	2.074	0.086	1.988	1000/10	4.815	9.988			"	9.988
20			66.79	64.79	-	1000/100	1.685	112.5	0.018		0.82	111.7
21			66.79	"	"	-	1.735	115.9	0.070		"	115.1

The results may be summarized thus:-

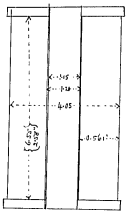
Taking Coil #16 as standard, and unity

The inductance of #17 is 1.8 without core 1.936 with core $\mu^2 = 1.904$

- - - #19 - 3.06 - - 3.338 - - 3.367

Breaking stress of Fine Wires. July 16th

A platinum iridium wire enamelled 0.005 (0.002") was found to just break with 150 grammes weight. A soft copper wire of approximately the same diameter did not support more than 80g.



$2t = 0.009'' = .01778$ say $.018$

$\text{Sum} \begin{cases} 4.05 = 12.8825 \\ 1.20 = 1.1310 \end{cases}$

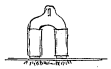
$11.7515 \times 6.55 = 76.96$ cc

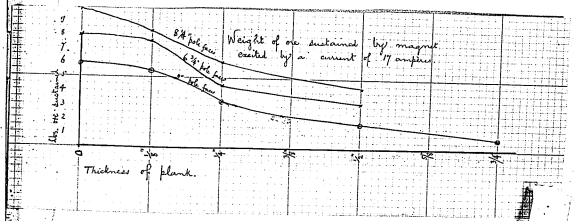
$t = 9\omega$

$\frac{R}{T} = 8.62 \quad \sqrt{8.62} = 2.94$

$\begin{array}{r} 4.05 \\ 1.20 \\ \hline 5.25 \end{array}$

$1.625 = 8.246$ cm. $= 3.247'' = .27'$




Weight of ms sustained by magnet carried by a current of 7 amperes
8 Wb per sq in
6·4 Wb per sq in
4 Wb per sq in
Thickness of plank.

Winding Calculation 19th July 1892.

$$d = -t + \sqrt{\{t^2 + 1.535 \times 10^{-3}\sqrt{\frac{k}{f}}\}}$$

$t = 0.009$
$t^2 = 0.81 \times 10^{-4}$

$0.081 \times 10^{-4} + 4.512 \times 10^{-3}$

$\sqrt{4.593 \times 10^{-3}}$

6.777×10^{-2}

$= 0.06777 - 0.009 = 0.05877$cm $= 0.0231$" covered $t = 0.039$" = #23 B&S.

$2.58 \div 0.039 = 86.0$ turns per layer
$0.561 \div 0.039 = 18.7$ layers
Say $85 \times 18 = 1620$ turns $\times 0.27 = 44.0'$ @ $0.02024 = 8.88\Omega$

$2.58 \div 0.030 = 86.0$ Say 82 turns $\times$ 19 = 1558 turns $\times 0.27 = 421.'$ $\times 0.02024 = 8.50\Omega$
$0.561 \div 0.030 = 18.7$

82 turns + 20 layers ($2.58" \times 0.6"$) completely filling spool = 1640 turns $\times 0.275 \cdot 451'$.
$451 \times 0.0202 \cdot 9.1\Omega$

Best result 1558 turns in 19 layers of 82 turns each #23 B.S. wire $0.0226"$ covered to $0.030"$ single cotton. Length $4.21'$ Weight 0.65 lb. Resistance @ 20° C. 8.50Ω
Two such spools will make a magnet holding $8+2'$, 1.3 lbs, 17Ω #23 B&S
Actual resistance as above 17.12Ω @ 23 °C.

Experiment on the Lifting Power of Ore Milling Magnets

One of the regular ore milling magnets was suspended above the floor, and wooden boards of different thicknesses laid against the pole faces. Ballast ore was then thrown up against the board and the quantity that would hold remain, weighed.
The curve shews the results.

The upper curve shews the effect produced by laying cast iron circular plates about 1/2" thick on the poles so as to increase the effective polar area.

Physiological Experiment July 21st 92.

Dr Peterson present.

A bundle of wire cotton covered copper wire was suspended on a wooden frame, so as to permit the introduction of the head into the centre of the coil. The internal diam: was about 25 the ext. diam: about 40 and the height about 30 . The mass about 70 kilos. The res: of this coil was 10.1Ω and its inductance

210.1×10^9cm $\times 3.2687^2 = 0.7286$ H

The current sent through this coil was about 1.85 amp: from 1200 volts mains. $E = pi\dot{c} = 890 \times 0.729 \times 1.85 = 1200$.

No sensation was perceptible to a person whose head was in the coil, when the current was started, interrupted, or maintained.

A bulb lamp was shut up in the spaces between the poles of a #3 Edison cast iron S.C. Motor from 12-20 to 23 cs. The field was excited during that time. No change was indicated by the dogs behaviour, due to the field.

Analysis of Diagrams taken from the E.C.E. Engine 2 × 200 KW at 85m 2s. on the 13th July, by W Phillips.

Stroke 30". R.p.m. 125 / 785 R.p.s. 2·083 / 7·17

Diams of H.P. cylinder 16.25", Area 205 sq ins Above 194 sq. ins below.
" " I.P. " 23·675" 447 436
" " L.P. " 38·5" 1164 1153.

Mean Pressure × R.p.s. × Area × 2·5 × 1·356 = Watts

Area × 2·5 × 1·356 for H.P. Upper 695 I.P. Upper 1815 L.P. Upper 3946
H.P. Lower 657·6 Lower 1478 Lower 3946

Engine Friction. 125 r.p.m. 2·083 r.p.s.

M.P. H.P. Upper = 1·84 lbs = 3·832 = 26620 M.P.H. Lower 0·29 lbs = 0·604 = 397
" I.P. " = 8·16 " = 16·99 = 25730 9·42 " = 19.62 = 29.000
" L.P. " = 1·12 " = 2·333 = 9206 1·56 " = 3·249 = 12,700
61,376 42,097
61,576

Total power exerted 103,673 watts

Load 2600 amp × 124 volts = 322,500 Watts electrical 113 R.p.m. = 1889 r.p.s.

M.P. H.P. Upper = 58·6 lbs = 110·3 = 76,620 Lower = 47·9 lbs = 90·2 = 59,330 137,970
I.P. " = 28·1 " = 52·91 = 80,160 = 28·25 " = 53·20 78,620 158,780
L.P. " = 6·49 " = 12·22 = 48,220 = 8·29 " = 15·61 = 61,030 109,250
205,020 198,980 404,000
Total activity 404,000

Nett efficiency of engine and dynamos 79·82 %

Load 3100 amp × 125·5 volt = 389,000 Watts electrical. 102 R.p.m. 1·7 R.p.s.

M.P. H.P. Upper = 69·2 lbs = 111·6 = 81,740 Lower = 61·1 lbs = 103·85 = 68,300 = 150,040
I.P. " = 32·2 " = 54·73 = 82,910 = 33·4 " = 56·78 = 83,920 = 166,830
L.P. " = 10·0 " = 17·0 = 67,080 = 11·6 " = 19·72 = 77,100 = 144,180
231,730 229,320 461,050
231,730
Total activity 460,050

Nett efficiency of engine and dynamos 84·38 %.

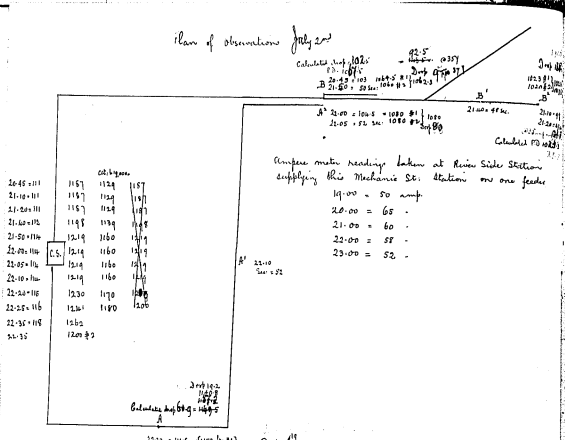
Measurements with the Large Experimental Electromagnet fitted with conical pole.

Each limit has 2728 turns of #19 B.W.G. S.C.C. Res: cool 26·27Ω

With the small explorer coil mounted on a wooden handle, and whose total equivalent area is 79 sq cms, the throw was 20 divs. at the polar distance employed with the frog in the experiments recorded on p. 90. The total flux was therefore $\frac{2·0 \times 10^8 \times 5·35 \times 10^{12}}{79} = 1354$

On closing up the poles to the distance employed with the ebonite ophthalmic, the throw was 70 divs = 4740.

Plan of observations July 2nd


Calculated drop 102.5
92.5
0.357
Drop 47.5 @ 37
B'
21·00 = 88 sec.
A' 21·00 = 120·5 + 1080 81 / 1080 drop 89
21·05 = 72 sec. 1088 89
Calculated PD 1063
Ampere meter readings taken at River Side Station supplying this Mechanic St. Station on one feeder
19·00 = 50 amp.
20·00 = 65 .
21·00 = 60 .
22·00 = 58 .
23·00 = 52 .
C.S.
A' 22·10 Sec = 52
Drop 102.5 1160.5 1058
Calculated drop 69 @ 1.5 = 103.5
22·20 = 111·5 (111·5 by 81 / 1151 / 1080 = 71)
22·25 = 93 sec.
Drop 69 @ 22·2 amp.
69 @ 23

	cable ages		
20·45 = 111	1151	1124	1151
21·19 = 111	1157	1124	1197
21·20 = 111	1157	1154	1197
21·50 = 112	1198	1194	1248
21·50 = 112	1219	1260	1249
22·20 = 112	1219	1260	1249
22·05 = 112	1219	1260	1249
22·10 = 112	1219	1260	1249
22·20 = 112	1230	1278	1249
22·25 = 112	1230	1280	1200
22·35 = 112	1230	1280	
22·35	1205		

At A 111·5 @ 21·20 = 111·5 × 116/118 ×

Res. of ℔ 4 BS. = 2.473×10^{-4} ω per foot, including return wire 4.946×10^{-4} per ft.

Assuming that the two feeding wires are parallel and 2 feet apart, their inductance per cm. of loop = $4 \log_e \frac{61}{0.26} + \frac{1}{4} = 14 \log_e 235 = 22.54$ + loop = mu

The resistance per foot of the loop = 4.946×10^{-4}

$p = 800$ $pl = 612.8 \times 10^{-6}$ $\frac{pl}{r} = \frac{612.8 \times 10^{-6}}{4.946 \times 10^{-4}} = 1.239$ $\left(\frac{pl}{r}\right)^2 = 1.5351$

$\sqrt{1+\left(\frac{pl}{r}\right)^2} = \sqrt{2.5351} = 1.592$

$\therefore e = 1.592$ or

for feeder B or = 51.9 e = 82.6 Observed e = 92.5

A or = 12.8 e = 20.4 " " = 19.2

Epitome of Measurements made on the 2nd and 9th July (99)
by Messrs Hammer, Lanman, & Latimer in Newark City Alternating systems.

The currents supplying the two feeders A & B on the 2nd July) were not separately observed, but their sum was observed, and is stated on the opposite page at hourly intervals from 19 to 23 oc.

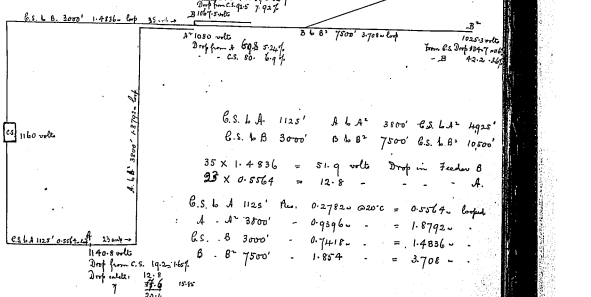
On the 9th July, readings were taken of the currents on the two feeders as follows:—

	20·00	20·15	20·30	20·45	21·0	21·15	21·30	21·45	22·0	Mean
A	29	29	29	29	29	29	29	29	29	29
B	44	44	43	44	45	44	44	44	44	44
A+B	73	73	72	73	74	73	73	73	73	73.

If we assume that this proportion was maintained the week previous the current in A + B would be on the 2nd July.

At	19 oc.	A+B 50	A 19.9	B 30.1
	20	65	25.9	39.2
	21	60	23.8	36.2
	22	58	23.0	35.0
	23	52	20.7	31.3
		285	113.2	171.9

At 22·35 pf: the voltmeter of the bus bar showed 1262 volts when that used on the line ℔ 2 showed 1200. Since ℔1 and 2 agree, and the resistance of ℔2 was found to be 1000 ω about coincident to the extent of 1000 ω on return to the laboratory, which would just make up the discrepancy, it is reasonable to suppose that all the readings were affected in this proportion. The following are the computed values of P.D. and current all reduced to 22·5 pf



C.S. & A 1125' A & A' 3100' C.S. & A' 4225'
C.S. & B 3000' B & B' 7500' C.S. & B' 10500'

35 × 1·4836 = 51·9 volts Drop in Feeder B
23 × 0·5564 = 12·8 " " " A.

C.S. & A 1125' Res. 0·2782 ω 20°C = 0·5564 ω loop
A . A' 3800' " 0·9396 " = 1·8792 "
C.S. . B 3000' " 0·7418 " = 1·4836 "
B . B' 7500' " 1·854 " = 3·708 "

Measurement of Inductance and the fall of pressure with alternating current in overhead wires.

July 22nd 1892.

Three #6 B.W.G. wires 0.203" diam. 0.2878 ohms resi. 4000' (3900' by rated) the wire ohms resi. long) were connected together at the box on the last pole. The res. by bridge was observed, as also the apparent inductance from the Galv. room:

I + II	1000~	2.911 Ω	0.794 Ω bal.	= 2.117 Ω	0.895 ¶	app. ind. = 2.695 millihenry
I + III	-	2.931 Ω		= 2.137	0.968 ¶	- - 2.837 - -
II + III	-	2.886 Ω		= 2.092 Ω	0.948 ¶	- - 2.736 - -
Bridge & E.R.	-	0.794			0.20	- - 0.199

Apparent resistances of loop I + II 2.117 Ω 2.406 mh.
" " " I + III 2.137 Ω 2.638 "
" " " II + III 2.092 Ω 2.537 "
6.346 7.581
3.173 2.527 mean.

Insulation of air 3 wires together 10,000 Ω abs.

Res. of ¶ I 1.081 Ω
" ¶ II 1.036 Ω
" ¶ III 1.046 Ω

Temp. of Bridge 26.7°C 2.740×10^{-3} ρ
" air in shade 29°C 2.89 "
Time Weather 4 noon 2.618 "

Set up a Westinghouse 30 k transformer in dynamo room, operated from the alternator. This was connected thro' a dynamometer to the overhead wires and the resistance board. The pressure on the line was measured by two Weston A.C. voltmeters, in succession.

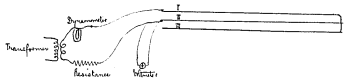
The corresponding measurements with continuous current were also made.

Loop	Dynamo	Γ	Amp.	Volts (I) observed by two voltmeters (II)	Mean	Res. by Bridge	Dynamo	Γ	Amp	Volts observed by two voltmeters	Mean	Impedance by mean	Impedance by Γ drop
I + II	206°	14.35	13.13	I 27.3 / II 27.03	27.175	2.070 Ω	163.5	12.78	11.70	I 35.4 / II 36.25	36.33	3.106	
	264	16.25	14.87	I 30.8 / II 30.6	30.7	2.064 Ω	175	13.23	12.11	I 37.6 / II 37.75	37.68	3.1123	
	352.5	18.77	17.17	I 36.0 / II 35.8	35.9	2.091 Ω	320	17.89	16.37	I 57.0 / II 57.0	57.0	3.115	1.449
						2.075 Ω						3.111 Ω	
I + III	213°	14.57	13.35	I 27.2 / II 29.1	27.15	2.034	209	14.26	13.23	I 39 / II 38.9	38.95	2.945	
	274	16.55	15.14	I 30.5 / II 30.75	30.63	2.023	2205	15.51	14.19	I 41.8 / II 41.5	41.65	2.936	
	358°	18.92	17.31	I 35.5 / II 35.25	35.38	2.044	332	18.22	16.67	I 49.6 / II 49.1	49.3	2.960	
						2.034						2.940 Ω	1.460 Ω
II + III	209	14.26	13.23	I 27.5 / II 27.0	27.25	2.060	212.3	14.57	13.33	I 40.3 / II 40.1	40.2	3.016	
	262	16.19	14.82	I 30.8 / II 30.5	30.65	2.069	336.0	15.33	14.03	I 42.6 / II 42.1	42.35	3.019	
	338.5	18.39	16.83	I 34.0 / II 34.5	34.25	2.059	311.0	17.64	16.14	I 49 / II 49	49.	3.036	
						2.062						3.024 Ω	1.467
												Mean	1.470

The results of these measurements are:-

The mean impedance is 47% greater than the resistance of three loops
" " angle of lag - 47° 8'
" " e.m.f. of inductance is 7% greater than the drop due to cr.
" " calculated distance between the wires is 13·1" (33·3 cms)

$1486 \times 6.2832 = 8898 \quad \log 8900 \cdot \beta$



$\left(1+\frac{p^2k^2}{r^2}\right) = 2.247 \quad \frac{p^2}{r^2} = 1.247 \quad \frac{pl}{r} = 1.117 \quad \frac{l}{r} = 1.255 \times 10^{-3}$ apparent $l = 2.644$ mh.

$\left(1+\frac{p^2k^2}{r^2}\right) = 2.088 \quad \frac{p^2}{r^2} = 1.088 \quad \frac{pl}{r} = 1.043 \quad \frac{l}{r} = 1.172 \times 10^{-3}$ app $\frac{l}{r} = 2.383$ mh.

$\left(1+\frac{p^2k^2}{r^2}\right) = 2.152 \quad \frac{p^2}{r^2} = 1.152 \quad \frac{pl}{r} = 1.073 \quad \frac{l}{r} = 1.206 \times 10^{-3}$ app $\frac{l}{r} = 2.458$ mh.

233
1·0777

7673
2.491

4000' = 12190 cms. & that l per cm. of loop = 20.43

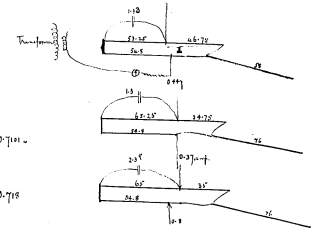
Neglecting static capacity $1 + k\log_e \frac{l}{r} = 20.43$

$\log_e \frac{l}{r} = 19.43/4 = 4.858$

$\frac{l}{r} = 129$

$r = 0.2579$

$k = 33.26 = 1.091' = 13.092"$



$59.8 \times 0.02433 \times \frac{34.75}{65.25} = 0.7101\ \omega$

$54.8 \times 0.02433 \times \frac{25}{65} = 0.718$

1.00028 L @ $\frac{28.6}{16.9 + C.}$ $\times 1.03$ = 0.351

log 1·00028 = 0·00012157
log 1·00351 = 0·00122872
0·99890226 = 1·00234 L @ 21.6°C.

log 9889 99515214
9966 99411411
·0011113 1·00233

0·99890226 / 0·99006532 = 1·001146 ⊠ @ 28.6 Shunted by 1000Ω = 1·000146 C

$\frac{2753}{2855} = \frac{965}{991·5}$ log = 2753· 143988062
2855· 145530118
98458044
99·5 99462927
98521117
98941114 9·7322 ×10⁻² = 0.09732 Ω

9·737 0.09737 Ω

log 965 98456444
9915 99728966
·8816076 10274 0.10276 Ω @ 24°C

27527
2691
log 5433·7 3·73509457
log 2752·7 3·43977589
0·29531868
log 0·09737 2·98841111
1·28374822
2·69307046 0.04932 Ω

Inductance Measurements.

A loop of iron wire radius 0.027 c.c. & diameter of 0.070. had a length of 58.1 cms with the two sides pulled close together.

Res: of slide wire AB 0.222 per cm. platinoid.
" " AC 0.0243 " manganin
E.M.F used uniform ripple by alternator. Current in supply mains measured. Telephone employed.

With 0.3 amp Res: = 0.1987 ω. Inductance $1.13 \times 57.3 \times 0.222 \times 1.1987 \times 10^{-6} = 15.710 \times 10^{-6}$ Henry
Inductance per cm. of loop = 270.22 cms

With increased to 0.44 amp Res = 0.1971 ω
Inductance $1.33 \times 57.25 \times 0.222 \times 1.1971 \times 10^{-6} = 18.41 \times 10^{-6}$ Henry
Inductance per cm. of loop = 317.4.

Bare iron wire in a loop. The sides of which were separated by glass. Radius of wire 0.0295 Length of loop 76. distance between axes 0.4.

With 0.37 amp supplied. Res = 0.7101 ω Inductance $1.3 \times 65.25 \times 0.222 \times 0.7101 \times 10^{-6} = 13.37 \times 10^{-6}$ Henry
Inductance per cm. of loop = 175.9

With 0.8 amp supplied. Res = 0.7180 Inductance $2.3 \times 65 \times 0.222 \times 0.7718 \times 10^{-6} = 23.83 \times 10^{-6}$
Inductance per cm. of loop = 313.5.

The last observation is not very accurate. When the current strength is increased the suppression of the fundamental note is more difficult to observe.

Measurement of Standard Resistance.

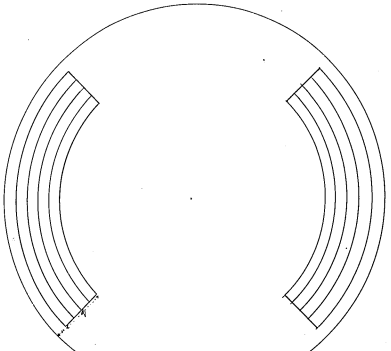
Aug. 2nd 92.

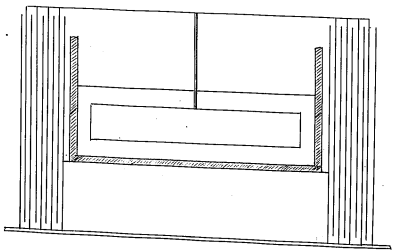
Res. of Nth. Diff. Galvo. 5506.2 @ 24.2°C. 100/000
7
5505·3
2752.65 Ω each coil

Comparison of my standard ohm @ 28.6°C. and spiral ½th, in manganin Bridge subdivision 100 in 995. In Galvo. = 0.09737 ∝ @ 24°C.

Comparison of my standard ohm @ 24.6°C. (1.001146 ⊠ & 1 coil) and substandard ½th Ω of manganin in wood. = 0.10276 ∝ @ 24°C.

Comparison of grid in series against spiral ½th.
2681 Ω added to spiral. Res. 0.04932 Ω @ 24°C.





Design for a Static Voltmeter to operate on 120 volts.

The fundamental equation is $\theta_{rad} = \frac{\Sigma h r V^2}{8\pi d}$ for the moving moment

and $= \frac{Mg f \sin\theta}{l}$ - - restituting -

where Σ = the summation of active surfaces
h = - height of each active surface
r = - radius - - - -
V = - emf in statvi units
d = - distance between opposing surfaces
g = - gravitation acceleration
f = - distance between threads of lifter
θ = - angle of deviation
M = - mass of suspended system
l = - length of each suspending wire

In order to indicate 100 volts @ 60° deviation, where $\sin\theta = 0.866$ moment of the existing 500-volt meter being 70 dyne-cms, that of 100 is 0.62 @ 60°. we may allow half this or 30.0 dyne cms. at 60°.
As shown on the opposite page, there are 16 active surfaces.

$V^2 = 1/9$ @ 100 volts
$d = 0.15$
$8\pi d = 3.771$
$\Sigma r = 16 \times 5.65 = 90.4$
$\therefore h = \frac{30 \times 3.771}{90.4 \times 0.1111} = 11.26.$

Allowing a moment of 20 dyne cms @ 60°. we have

$h = 7.5$

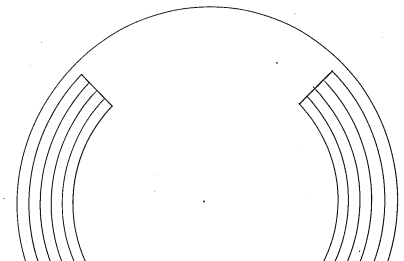
accompanying scale shows the relative advantage of employing a lifter panel with a unifilar suspension. The last 16⅔% of the reading occupy 1.64 times as much length of scale as with unifilar suspension. With mean radius of 5.45 cms. the $\frac{\text{circ.}}{2} = 8.56$ cms. The surfaces of vanes will be $8.56 \times 8 \times 7.8 = 534.2$ sq cms. Say 600 sq cms in all. mass of the will be 60.97 gms. The total mass say 55 gms.

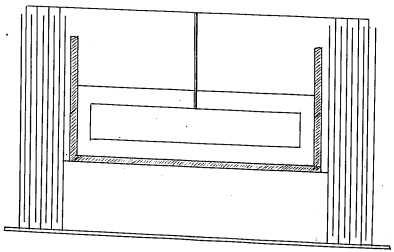
$f^2 = \frac{4 \pi l \rho_{rad}}{Mg \sin\theta}$

$= \frac{4 \times 13 \times 20}{55 \times 981 \times 0.5} - \frac{10^2}{2.698 \times 10^4} = 3.855 \times 10^{-3}$

$f = 0.1963$ say 0.2

As constructed the outside distances of = 1.80 each wall 0.093
The width of groove 0.346. Thickness of vanes 0.032. Clearances 0.157.
Height of walls 7.55 of Vanes 7.575. Mass of suspended system 65.71 g.
Distance of 0.9. below vane plate 2.8. Pointer radius 15.6. Mean vane radius 5.6. Suspension line length between clamps 12.6. Upper distance between wire axes 1.457 x10¹ Lower 1.918 x10¹. geometrical Mean 1.672 x10⁻¹





Design for a Static Voltmeter to operate on 120 volts.

The fundamental equation is $\theta_{rad} = \frac{\Sigma h r V^2}{8\pi d}$ for the moving moment

and $= \frac{Mg\frac{f}{2}\sin\theta}{\frac{l}{2}}$ - - restituting -

where Σ = the summation of active surfaces
h = - height of each active surface
r = - radius - - - -
V = - emf. in statvi units
d = - distance between opposing surfaces
g = - gravitation acceleration
f = - distance between threads of bifilar
θ = - angle of deviation
M = - mass of suspended system
l = - length of each suspending wire

In order to indicate 100 volts @ 60° deviation, where $\sin\theta = 0.866$
The moment of the existing 500-volt meter being 70 dyne-cms, that of
at 90° or 60.62 @ 60°. we may allow half this or 30.8 dyne cms. at 60°.
As shewn on the opposite page, there are 16 active surfaces.

$V^2 = 1/9$ @ 100 volts
$d = 0.15$
$8\pi d = 3.771$
$\Sigma r = 16 \times 5.65 = 90.4$
$\therefore h = \frac{30 \times 3.771}{90.4 \times 0.1111} = 11.26.$

Allowing a moment of 20 dyne cms @ 60°. we have

$h = 7.5$

The accompanying scale shews the relative advantage of employing a bifilar as compared with a unifilar suspension. The last 16⅔% of the reading occupy 1.64 times as much length of scale as with unifilar suspension.

With mean radius of 5.45 cms. the ~~equiv~~ equiv. = 8.56 cms. The surfaces of the vanes will be $8.56 \times 8 \times 7.8 = 534.2$ sqr cms. Say 600 sqr cms in all. The mass of this will be 60.97 gms. The total mass say 55 gms.

$f^2 = \frac{4 l p_{in}}{Mg \sin\theta}$

$= \frac{4 \times 13 \times 20}{55 \times 981 \times 0.5} = \frac{104 \times 10^2}{2698 \times 10^2} = 3.855 \times 10^{-2}$

$f = 0.1963$ say 0.2

As constructed the outside distances of = 1.80 each walls 0.043
The width of grooves 0.346. Thickness of vanes 0.032. Clearances 0.157.
Height of walls 7.55 of Vanes 7.575. Mass of suspended system 60.71 g.
Distance of 0.3. below vane plate 2.8. Pointer radius 15.6. Mean vane
radius 5.6. Suspension wire length between clamps 12.6. Upper distance
between wire axes 1.457×10^{-1} Lower 1.9185×10^{-1} geometrical Mean 1.672×10^{-1}

log 9.899 = 9.951526
log 9.866 = 9.946611
1.00293 0.004915

$\frac{2799.7}{2800.4}$ $\frac{2799.7}{3590.4}$

$\frac{9.8216 \times 3590.4}{2800.4 \times 1.00233} = 0.0012556$

0.021 × 30 = 0.63%

$9.76 \times 10^{-3} \times 1.0063$ log 9.76 = 3. 989435
− 1.0063 . 0.002715
9.8216 3.991720

log 9.8216 = − 3. 991720
+ 1.00233 = 0.000001
− 3.991719
+ 1799
log 3590.4 = 555 0 dp 3
2546313
− 2800.4 = 447220
1.2563 ratio 2099093
0.002738
1.2485 at 60°C 2.096363

Comparison of Grid Resistance with the 0.01Ω Standard. July 24th

(10Ω added to 2Ω coil)

Res. of H.B. Gulcher coils, pratically differentiated 7599.4Ω by Bridge @ 29°C
Current of about 6 amp. passed through grid & 0.01Ω coil in series. (minutes)
Balance effected by 790Ω added to grid. Leads each 0.7Ω
Res. of grid @ 30°C = 0.0012556 Ω

Test of Carrying Capacity of conductor Siemens Cable Sample from Schenectady July 27th 92.

This is a 30ft length of lead covered siemens cable, jute core # 6 B.W.G. intended for pressures up to 3000 volts.
The length between soldered pressure wires at end of jute = 918.5 = 361·6" (30·15' / 30·1·6)

diameter of conductor	0.426	=	0.1673"
" over jute	1.022	=	0.4023"
Thickness of jute	0.298	=	0.1173"
diameter of lead cable	1.426	=	0.5615"
Thickness of lead cover	0.064	=	0.0252"
Mass of sample	7.37 lb	=	16.258lb
" per cm.	8.025gm		
" per foot		=	0.5392 lb.
" " mile of 5280'		=	2847 lbs.

Area 0.14186
Circ 1.3352

The cable was laid out straight on the stone floor, in circuit with the grids in multiple, and the following measurements made:-

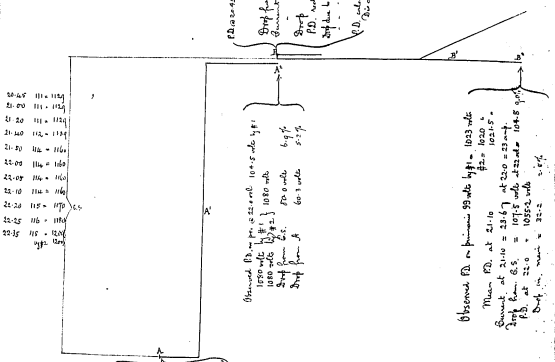
Temp Start	C°	Watts per cm.	Elevation of Temp											
19·5°														
20·														
21·														
22·														
23·	772·8	0.0100	17°c.											
24·														
25·	2352·3	0·0311	23°c.											
26·														
27·														
28·	4569·8													
29·		0·0625	33°c.											
30·5														
31·5														
36·	7106·5	0·0949	39·5°c											
36·5														
36·5	6272·7	0·0838	36°c. 25°c abs absolute											

No.	Res. of each Gr. unit	Res. added	Ratio	Standard @ Rat.	Res. of wire @ Temp	Res. per cm. @ Temp	Resistivity @ 0°c	$\frac{R}{T_0 c}$	Temp of wire	P.D. on grids	Current thro wire	Current thro wire
1	2815.	200 1058	1.0716	1.2577	1.1730	1.277	19120 39°C			0.100		
1a							16·162 0°C					
2		200	1.0716		1.1730	1.277	Cond. 0.0368			0.340		
2a		160	1.0568		1.1891	1.295		1.1213	30°c	0.340	11·30	
								1.193	47°C	0.360	16.0	27·8
4		120	1.0426		1.206	1.313		1.210	50°	0.597	15.01	
5		110	1.0391		1.2077	1.317		1.214	52°	0.610	·15	
6		105	1.0373		1.2119	1.319		1.216	52·	0.610	·20	
7		100	1.0355		1.214	1.322		1.2182	53°	0.615	·20	4.85
8		17	1.0060		1.2097	1.361		1.2284	61°	0.750	·31	
9		7	1.0025		1.2574	1.365		1.2582	62°	0.85	50	
10		0	1.		1.257	1.368		1.2615	63°	0.850	55	67.6
11		0	1.		1.257	1.368		1.2615	63°	0.857	16·00	
12		0	1.		1.257	1.368		1.2615	63°	1.015	·01	
13		−80 added from	1.0284		1.293	1.408		1.2972	71°		·25	
14		− 65	1.0231		1.286	1.140		1.2905	69·5	1.060	·25	84·3
15		− 50	1.0178		1.2795	1.393		1.2814	68·	0.979	17.15	77·9
16		−50	1.0178		1.2795	1.393		1.2814	68·	0.995	18·00	79·2

Temp of lead ambient 22°c.

Determination of Matthiessen's Temp: Coeff: in Copper from 10° to 100°C.

t	t'c	t²	0·003876	1 − 0·003876	0·00000 9009 t³	C_t	$\frac{R_t}{R_0}$	log $\frac{R_t}{R_0}$	
40	40·00	16 × 10²	0·15480	0·846520	0·000413	0·859681	1·16338	0·06550	
41	41·00	1·681	0·15867	0·846133	0·000418	0·856147	1·16775	0·06754	0·00204
42	42·00	1·764	0·16254	0·837746	0·000423	0·852596	1·17218	0·06958	0·00204
43	43·00	1·849	0·16641	0·833359	0·000428	0·849025	1·17674	0·07162	0·00204
44	44·00	1·936	0·17028	0·829972	0·000433	0·845436	1·18143	0·07366	0·00204
45	45·00	2·025	0·17415	0·825585	0·000438	0·841809	1·18624	0·07570	0·00204
46	46·00	2·116	0·17802	0·822198	0·000443	0·838184	1·19118	0·07774	0·00204
47	47·00	2·209	0·18189	0·818811	0·000448	0·834533	1·19625	0·07978	0·00204
48	48·00	2·304	0·18576	0·814424	0·000453	0·830864	1·20145	0·08182	0·00204
49	49·00	2·401	0·18963	0·810037	0·000458	0·827176	1·20679	0·08386	0·00204
50	50·00	2·500	0·19350	0·806650	0·000463	0·823470	1·21226	0·08590	0·00204
51	51·00	2·601	0·19737	0·802263	0·000468	0·819745	1·21786	0·08794	0·00204
52	52·00	2·704	0·20124	0·797876	0·000473	0·816002	1·22359	0·08998	0·00204
53	53·00	2·809	0·20511	0·794489	0·000478	0·812240	1·22946	0·09202	0·00204
54	54·00	2·916	0·20898	0·791102	0·000483	0·808459	1·23547	0·09406	0·00204
55	55·00	3·025	0·21285	0·787715	0·000488	0·804660	1·24161	0·09610	0·00204
56	56·00	3·136	0·21672	0·783328	0·000493	0·800842	1·24790	0·09814	0·00204
57	57·00	3·249	0·22059	0·779941	0·000498	0·797005	1·25432	0·10018	0·00204
58	58·00	3·364	0·22446	0·775554	0·000503	0·793150	1·26089	0·10222	0·00204
59	59·00	3·481	0·22833	0·771167	0·000508	0·789276	1·26759	0·10426	0·00204
60	60·00	3·600	0·23220	0·766780	0·000513	0·785383	1·27443	0·10630	0·00204
61	61·00	3·721	0·23607	0·762393	0·000518	0·781472	1·28141	0·10834	0·00204
62	62·00	3·844	0·23994	0·758006	0·000523	0·777542	1·28853	0·11038	0·00204
63	63·00	3·969	0·24381	0·753619	0·000528	0·773593	1·29579	0·11242	0·00204
64	64·00	4·096	0·24768	0·749232	0·000533	0·769626	1·30320	0·11446	0·00204
65	65·00	4·225	0·25155	0·744845	0·000538	0·765640	1·31075	0·11650	0·00204
66	66·00	4·356	0·25542	0·740458	0·000543	0·761635	1·31845	0·11854	0·00204
67	67·00	4·489	0·25929	0·736071	0·000548	0·757611	1·32629	0·12058	0·00204
68	68·00	4·624	0·26316	0·731684	0·000553	0·753568	1·33428	0·12262	0·00204
69	69·00	4·761	0·26703	0·727297	0·000558	0·749507	1·34242	0·12466	0·00204
70	70·00	4·900	0·27090	0·722910	0·000563	0·745427	1·35071	0·12670	0·00204
71	71·00	5·041	0·27477	0·718523	0·000568	0·741328	1·35915	0·12874	0·00204
72	72·00	5·184	0·27864	0·714136	0·000573	0·737211	1·36774	0·13078	0·00204
73	73·00	5·329	0·28251	0·709749	0·000578	0·733075	1·37648	0·13282	0·00204
74	74·00	5·476	0·28638	0·705362	0·000583	0·728920	1·38537	0·13486	0·00204
75	75·00	5·625	0·29025	0·700975	0·000588	0·724746	1·39442	0·13690	0·00204
76	76·00	5·776	0·29412	0·696588	0·000593	0·720553	1·40362	0·13894	0·00204
77	77·00	5·929	0·29799	0·692201	0·000598	0·716342	1·41298	0·14098	0·00204
78	78·00	6·084	0·30186	0·687814	0·000603	0·712112	1·42249	0·14302	0·00204
79	79·00	6·241	0·30573	0·683427	0·000608	0·707863	1·43216	0·14506	0·00204
80	80·00	6·400	0·30960	0·679040	0·000613	0·703596	1·44198	0·14710	0·00204
81	81·00	6·561	0·31347	0·674653	0·000618	0·699311	1·45196	0·14914	0·00204
82	82·00	6·724	0·31734	0·670266	0·000623	0·695007	1·46210	0·15118	0·00204
83	83·00	6·889	0·32121	0·665879	0·000628	0·690686	1·47240	0·15322	0·00204
84	84·00	7·056	0·32508	0·661492	0·000633	0·686346	1·48285	0·15526	0·00204
85	85·00	7·225	0·32895	0·657105	0·000638	0·681989	1·49347	0·15730	0·00204
86	86·00	7·396	0·33282	0·652718	0·000643	0·677613	1·50424	0·15934	0·00204
87	87·00	7·569	0·33669	0·648331	0·000648	0·673219	1·51518	0·16138	0·00204
88	88·00	7·744	0·34056	0·643944	0·000653	0·668807	1·52628	0·16342	0·00204
89	89·00	7·921	0·34443	0·639557	0·000658	0·664376	1·53754	0·16546	0·00204
90	90·00	8·100	0·34830	0·635170	0·000663	0·659927	1·54896	0·16750	0·00204
91	91·00	8·281	0·35217	0·630783	0·000668	0·655460	1·56055	0·16954	0·00204
92	92·00	8·464	0·35604	0·626396	0·000673	0·650975	1·57230	0·17158	0·00204
93	93·00	8·649	0·35991	0·622009	0·000678	0·646472	1·58421	0·17362	0·00204
94	94·00	8·836	0·36378	0·617622	0·000683	0·641951	1·59629	0·17566	0·00204
95	95·00	9·025	0·36765	0·613235	0·000688	0·637412	1·60854	0·17770	0·00204
96	96·00	9·216	0·37152	0·608848	0·000693	0·632855	1·62096	0·17974	0·00204
97	97·00	9·409	0·37539	0·604461	0·000698	0·628280	1·63355	0·18178	0·00204
98	98·00	9·604	0·37926	0·600074	0·000703	0·623687	1·64631	0·18382	0·00204
99	99·00	9·801	0·38313	0·595687	0·000708	0·619076	1·65924	0·18586	0·00204
100	100·00	10·00	0·38700	0·591300	0·000713	0·614447	1·67235	0·18790	0·00204



1·4936×3·542 = 2·362Ω
0·5564×1·542 = 0·8582Ω

0·8582Ω = 19·7 " = 22·2Ω
58 − 22·2Ω = 35·8Ω drop. Ckt. total. 72·6 Ω 11·5

50 × 2·362 = 70·8Ω Ω 11·5.
28 × 0·8582 = 24·2 " 5·1

70·6 + 24·2 = 30·73 amp
58 − 30·7 = 27·3 × 0·8582 = 24·2
16·7
4·5 volts.

The distribution of current best according with the figures = 30⅞ amp along B
27¼ " " A
with 4·5 volts to high a pressure at A in consequence, that at B ok.

Epitome of Measurements made on the 2nd and 9th July

by Messrs Hammer, Lamman, & Latimer, in Newark city alternating system.

The currents assumed on page 99. have been found to be misdirected, the greater, actually) passed along A, and the lesser along B. With this modification the case stands as follows:-

---

Winding for an alternating current Motor Meter

that shall have the same dimensions as that already constructed and whose specification appears on page 76, but which shall have more turns in order to start on one ampère.

Aug. 2nd

The starting current of the present model being 3.5 amp, we require twice as many turns on both field and armatures.

The two external coils can each be 4 layers of 9 turns # 15 B.W.G. = 36 turns, 0·072" c.c. to 0.080", instead of 3 layers of 6 turns = 18 turns # 12 B.W.G. The total length of wire will be 72×1·5 = 108' = 1.7 lbs and 0·216 ω

The four internal coils can each be 4 layers of 12 turns = 48 turns or 48' # 19 B.W.G. 0.042" s.c.c. to 0.050". The total length of wire will be 192' = 103 lbs and $\frac{1.733}{4}$ = 0·281 ω. Total res: 0·5ω

Drop 5 volts at 10 amp. and full = $\frac{48 \times 36}{27 \times 19}$ = 3.55 turns on yoke.

Test of this meter on completion 24th August

Lamps	Block	Amp.	R.p.m.	R.p.m.-p.w.		
3	0·275	1·419	78	5·5		
4	0·358	1·847	15·5	8·39		
5	0·440	2·271	21·0	9·25		
6	0·532	2·745	26·7	9·73		
8	0·718	3·706	37·5	10.14		
10	0·850	4·386	47	10.72		
12	1·025	5·289	56	10·59		
14	1·120	5·831	63	10·8		
16	1·310	6·760	72	10·65		
18	1·450	7·482	78·5	10·49		
20	1·620	8·358	86	10·29		
22	1·760	9·080	93·5	10·30		
24	1·980	10·22	107	10·47		
			(only static			

Res: 0·50 ω @ 20°C.
Inductance 0·86 to 0·92 mh. according to position of armature.
Mean " 0·74 mh. Mean impedance @ 140 ω 0·83ω.

2839.6
8445
37846
2839.6
5785085
4533419
1247666

log 9799 = 9911818
1159484

1.306 × 10⁻²

1306
1287
2563
1232

log 98216 =

Time	Res: of coil at Ordinary temp.	Res: added for heating	Ratio	Standard Res: at temp.	Res: of coil at temp.	Res: per cm.	Resistivity @ 0°C.	$\frac{R}{r}$	Temp. of room	P.D. in volts
20-45				1·193 × 10⁻²						
21-00				1·0746						
21-20	50 2823·7	2·10	1·0746	0·01282 × 10⁻²	1·299 × 10⁻²	1·299 × 10⁻⁴	1631 Ω	1·0945		0·0720
21-40										
21-50	11 mg	2·05	1·0726		1·295 ·	1·301 ·	97·7% cond.	1·002	0·5° 29·5°	0·337
22-00	15·30	2·05	1·0726		1·195 ·	1·301 ·		1·002	0·5 29·5	0·350
22-05										
22-10	31	1·95	1·0694		1·199 ·	1·305 ·		1·005	1·2° 30·2	0·550
22-20	43	1·92	1·0680		1·200 ·	1·306 ·		1·006	1·5° 30·5	0·555
22-25	58	1·92	1·0680		1·200 ·	1·306 ·		1·006	1·5° 30·5	0·555
7	16·00	1·65	1·0585		1·211 ·	1·318 ·		1·015	4° 33.	0·615
8	·10	1·55	1·0549		1·215 ·	1·323		1·018	4·6° 33·6	0·626
9	·20	1·55	1·0549		1·215 ·	1·323		1·018	4·6 33·6	0·626
10	·25	1·20	1·0425		1·230 ·	1·339		1·031	8° 37	1·071
11	·35	1·15	1·0407		1·232 ·	1·341		1·033	8·5° 37·5	1·085
12	·40	0·70	1·0177		1·260 ·	1·372		1·056	11·3° 42·3	1·235
13	·50	0·60	1·0212		1·254 ·	1·365		1·051	13° 42	1·230
14	17·00	0·32	1·0113		1·267 ·	1·379		1·062	15·3° 44·3	1·310
15	·10	0·25	1·00885		1·271 ·	1·384		1·066	16·7° 46·7	1·378

The thermal resistance = $\int \frac{d\rho}{2\pi r} = \frac{\rho}{2\pi} \log_e \frac{R}{r}$

Heat transfer in Watts per sec. = $\frac{2\pi (V_1 - V_2)}{\rho \log_e \frac{R}{r}}$

$\therefore \rho = \frac{2\pi (V_1 - V_2)}{H \log_e \frac{R}{r}}$

$\log_e \frac{R}{r} = 0.87755$

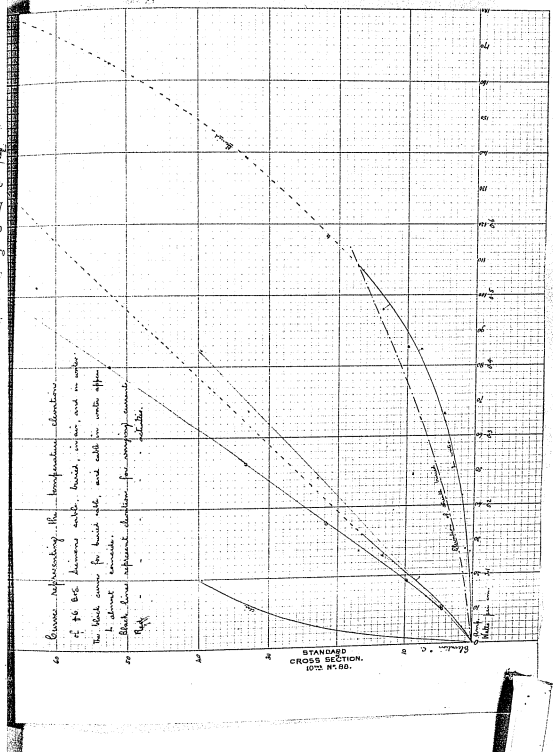
$\frac{2\pi}{\log_e \frac{R}{r}} = 7.16.$

I Watt = .1/4.2 w.s per sec.

$R = \frac{H \log_e \frac{R}{r}}{(V_1 - V_2) 2\pi}$

R. (a) ρ = 7.50 = 104.75

log 2·405 = 0.3811151
log 3811151 = −1·581056
0·3622187
−1·943271


Curves showing the temperatures elsewhere
a, b, c, d, e, f, g, h, i, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z
the black curve for heat rise, and cold fall
1 minute
Black lines represent distances for varying curves
Watts
STANDARD
CROSS SECTION.
10·2 M·M.

Carrying Capacity of Siemens Cable contd.

Placed the length of cable, whose heat in air appears on page 103, in an iron pipe 880 cms long, 3·3 cms (1·3 ") inside diam: and 4·127 (1·625") outside diameter with short right angles allowing at each end. This pipe was kept filled with flowing water. 7 cms. of cable projected above the water at one end, and 20 cms at the other, measured from the water's edge to the pressure-wire soldering. The length of cable immersed in water was thus 891·5 cms. The rate of flow of the water was 47 c.c. per sec. through the tube during the test.

Current thro. wire	Temp. of water	Temp. about above water	C^2	Watts per linear cm.	Temp. of air	Thermo per linear cm.	$\frac{2\pi}{H \log_e \frac{q}{p}}$	ρ C.G.S. per cc.	K.
5·62	·2°C.	0	31·58	4.102×10^{-4}	3·2°C.	0.9768×10^{-5}			
26·29		0·5	691·2	5.992×10^{-3}		2.141×10^{-5}			
27·31	28 | 26·5	28·3 1·2	745·84	9·702 "		2·310 "			
42·92	25 | 22·7	23·4 1·8	1842.	0·02403		0·005721.			
42·92	~~24 | 24·3~~	~~24·6~~ 1·9	1842.	0·02406	31°C.	0·005729	1252	2378	4.205×10^{-6}
42·92		24·8 1·7	1842.	0·02406		0·005729	1252	2128	4.699×10^{-6}
63·77	28·8 | 29·2	29·0 1·0	4066·7	0·05360	31·5°C.	0·01276	561·2	2245	4.454×10^{-6}
64·44		29·1 4·8	4152·5	0·05493		0·01308	547·3	2463	4·060 "
64·44		29·2 4·4	4152·5	0·05493		0·01308	547·3	2408	4·153 "
84·10	29·0 | 29·5	29·3 7·7	7072·8	0·09417	32°C	0·02255	317·5	2445	4·090 "
84·66		29·5 8·0	7167·3	0·09561		0·02288	312·9	2503	3·995 "
97·92	29·0 | 29·2	29·7 13·6	9584·64	0·1315	32°C	0·03131	228·7	3110	3·215 "
95·95		29·4 13·6	9206·42	0·1257		0·02993	234·2	3253	3·074 "
106·10	28·4 | 29·6	29·1 15·7	11236.	0·15349	30·5°	0·03688	194·2	3049	3·280 "
107·5		29·1 16·6	11550.	0·15799		0·03807	188·1	3122	3·203 "

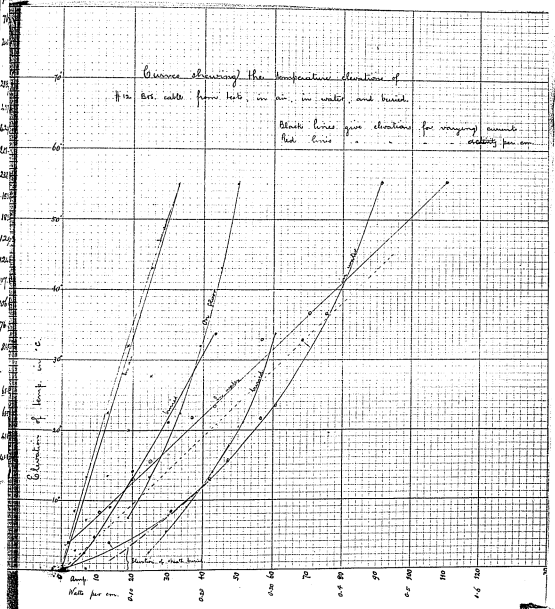
5·383 @ 28°C. = 14·539 $\times 10^{-5}$ @ 0°C. = 1547

No. of Obs.	Time	Res. of G. coils	Res. added for balance	L	Ratio	Res. of S.C. @ limit	Res. of wire	Res. for unit	Resistivity @ 0°C	$\frac{R_t}{R}$	T_{abs} (calc.)
								$= 5·383 \times 10^{-5}$	1547		
1	15·45	2842·	30	wire	1·0356	0·01493	0·014933	5·383		1·1128	28·7
2	·55		35		1·0423		0·014990	5·387	= 99·6 ohms	1·1136	28·9
3	·57		40		1·0461		0·015099	5·435		1·1235	30·1
4	16·00		45		1·0465		0·015086	5·468		1·1302	31·2
5	·07		50		1·0476		0·015016	5·475		1·1317	32·5
6	·10		90		1·0317		0·015086	5·551		1·1473	36·2
7	·16		101		1·0355		0·015105	5·571		1·1516	37·2
8	·20		162		1·0570		0·015210	5·686		1·1753	42·5
9	·29		150		1·0528		0·015190	5·664		1·1710	41·9
10	·40		182		1·0640		0·015245	5·724		1·1832	44·7
11	·42		178		1·0626		0·015237	5·716		1·1815	44·2
12	·44		220		1·0774		0·015311	5·796		1·1980	48·9
13	·50		240		1·0844		0·015346	5·835		1·206	50·0
14	·51		265		1·0932		0·015390	5·881		1·215	52·0
15	17·03		260		1·0915		0·015381	5·873		1·2111	51·7
16	·15		350		1·123		0·015536	6·041		1·249	59·9
17	·24		369		1·130		0·015570	6·079		1·2567	60·7
18	·25		410		1·1444		0·015640	6·155		1·2722	65·2
19	·37		412		1·145		0·015645	6·160		1·2732	65·3
20	40		617		1·217		0·015998	6·546		1·3530	83·7
21	45	2837	620		1·218		0·016002	6·552		1·3543	84·1

$\frac{R}{d} = 0.645$ $\frac{R}{d} = 3.1462$ $\log_{10} = 0.4977863$ $\log_e \frac{6.9704}{3.02256} = 1.13462$

$\log_e \frac{R}{d} = 1.14462$

$\frac{2\pi}{\log_e \frac{R}{d}} = 5.1482$


Curves showing the temperature variation of
#12 Brs. cable from kink in air, in water and buried.
Broken lines give variations for increasing current
Full lines " " " decreasing current
Temp. abs.
Amp.
Watts per cm.
Hours & minutes

Carrying Capacity of Siemens Cable contd.

29th July.

The next sample tested was a 20 ft. length of small cable # 12 B+S.

Diam: of conductor		0.205	(0.0808")
Area	"	0.0330	0.005115.0"
Circ.	"	0.6414	0.253"
Thickness	jute	0.22	0.0866"
Diameter	"	0.6845	0.2694"
Thickness	lead	0.1174	0.04624"
Diameter	"	0.873	0.3446"

Length between pressure wire, at end of jute 916.3 mm. (360.8")
Length of live 909.
Jute 3.3 at one end 4.0 at other.

This cable was placed in the same water pipe described on preceding page, 14 cms. projected above water level to pressure wire at one end, and 15.5 at the other.

Current	E.	Observed	E.	Gain C^2	Volts per 1 mm.	Temp. of water	Temperature	Elevation of temp.	Thermal conductivity	ρ	K.
0.365	7.4054			54.82	0.00245	from 37.0 to		0°	0.0007024	—	
0.368	7.4462			55.71	0.00300	47.0 to 37.0	31.6° 33.1°	0.3°	0.0007143	23.038	0.0001302
0.624	13.265			175.9	0.00759	288 to 226		1.6°	0.002293	38.1	
						285		1.7			
0.668	13.149			182.0	0.00966	28.5		4.0	0.002295	9555	
1.536	31.15			970.3	0.0539	29.0 to 22.6		7.6	0.01283	3249	
1.530	31.03			962.9	0.0536	28.1		8.4	0.01276	3610	0.0002915
2.172	44.06			1941.3	0.1104	29.0 to 22.9		13.2	0.02628	2753	
2.062	41.82			1748.9	0.09904	28.7		13.0	0.02358	3622	0.0002960
2.308	46.82			2192.1	0.1255	28.7	32.7°	16.0	0.02988	2936	
2.308	46.82			2192.1	0.1253	28.1		15.6	0.02983	2965	0.0002448
2.736	55.5			3080.3	0.1786	29.3 to 28.8		14.5	0.04252	2515	
2.778	56.34			3174.2	0.1852	28.3		21.7	0.04409	2698	0.0002831
2.976	60.36			3643.3	0.1961	28.4 to 27.6		24.0	0.04677	2812	
2.990	60.64			3678.	0.2160	28.4 to 27.6		23.3	0.05143	2487	0.0002774
3.470	76.38			4953.3	0.2493	29.3 to 28.2		31.2	0.07126	2393	
3.370	68.35			4671.7	0.2840	28.8	31.6° 31.6°	32.9	0.06962	2668	0.0002953
3.730	75.64	14.04	72.44	5722.9	0.3522	29.0 to 28.1		36.5	0.08386	2390	
		14.34	74.00			28.7		36.6			0.0001184
4.532	91.92	16.20	83.58	8444.3	0.5231	30.0 to 28.7		95.0	0.1317	2290.	
4.520	91.68	16.17	83.42	8405.2	0.5207	28.7	31°C. 31°	85.3	0.1311	2312	0.0001318

Particulars obtained of damage occasioned by a thunderstorm in a house at Sydney C.B. over electric light wires supplied from an Edison 3-wire system, 10th August 1892.
from evidence collected on the 14th/15th August.

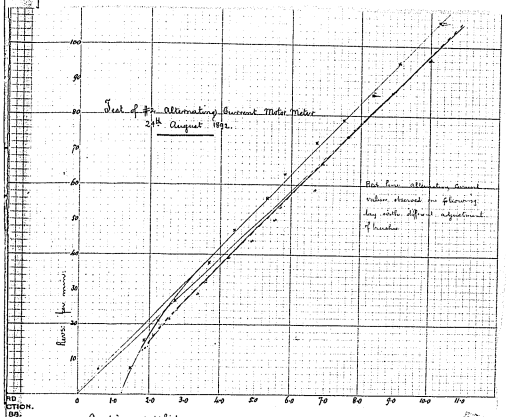
There are two electric light systems in Sydney, the T.H. and the Edison. The former is 2-wire and the latter 3-wire, both low tension continuous currents. The two central stations are close together and their respective pole lines run on opposite sides of nearly all the streets. Fully half a mile from the stations, southwards by the bay shore these pole lines pass the residences of J. Moseley & D. J. Kennelly facing on opposite sides of the road. The former is supplied by the Edison, the latter by the T.H. and the supply wires cross the road in each case. Beyond these houses, the Edison system continues to supply two or three customers up to a distance of half a mile. The T.H., one customer about 1/6th of a mile.

On the 10th Aug. the engines in the stations were started at about 19 or. At 20 or. the load was about 100 amps on each side of the Edison system, the evening dark with a heavy thunderstorm coming up from the S.W. at about 20.05 a thunderclap heard at these two houses followed the flash by an estimated interval of one second. so that the discharge was probably within 1200 feet of this locality. At this time there were 8 lamps alight in the Moseley House all on the ground floor. Coincidently with the discharge 16 lamps were broken on this and the first floor. No other damage occurred in the Moseley House, and no damage was reported from any other house in the two systems.

The 3 wires enter the Moseley residence at the back by a first floor window. Through fuse blocks, one of which melted at the time of the accident. They distribute to the various rooms. It was stated that not one of the lamps destroyed was burned on at the time, so that the discharge which broke them must have leaped their switches. The lamps actually alight flashed brightly for a moment, but did not break. The broken lamps were nearly all upon the first floor. At the station, a momentary kick was observed on the negative ammeter, by the engineer who stated that he was watching the instrument at the time, and the load fell from 110 to 80 amperes when the pointer next came to rest.

The conclusion suggested was that the lightning may have struck the ground near Moseley's house, and an induced disturbance made itself felt on the Edison system supplying him. Through the + side of the system it either did not pass, or passed through the lamps on the ground floor. On the — side the discharge broke the 16 lamps and fused the plug down by the momentary short circuit on the system.

The Edison system has one Wilt arrester on each bus bar at the door of the station, and no other lightning protection. The T.H. system has no arresters anywhere.


Test of ft Alternating Current Motor Meter
24th August 1892.
Revolutions
Amperes supplied.
For two sets of readings Current taken observed in following two cases. Different adjustment of Meter

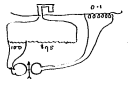
$\frac{25.6}{16.3}$ @ 0.03 = 351 1.003351

log 1.000328 = 0.000121579

" 1.003351 = 0.001527170

$\frac{0.001643320}{0.000101113}$ = 1.003379 log " @ 24.6°C.

$\frac{0.001063190}{}$ = 1.001146 " @ 25°.6 C



log $\frac{100 \times 2752}{2856}$ = $\frac{96.5 \text{ ω}}{991.5}$ = 0.097336 " @ 24.6°C

log 100 = 2.000434

" 2752 = 3.439646434

" 2856 = 3.455714985

1.983931449 = 96.392 ω

" 991.5 = 2.996 02927

1.983 12062 = .097321 " @ 24.6°C

Test of Alternating Current Motor Meter on Alternating current circuit 26th Aug. 92.

The test and curve obtained with this motor #2 are shewn on p. 105 with continuous current.

No of Obs	No of Comp	Coeff of Dynam	Dynam Deflen	$\sqrt{}$	Amps	Rpm.	Rpm/amp	
1	4				1·80	12·5		
2	5				1·86	13·0		
3	6	f_2 0·2325	70°	8·367	1·945	13·5		
4	7		95	9·220	2·144	17		
5	8		100	10·0	2·325	19.		
6	9	f_2 0·3744	80	8·944	3·267	28·4		
7	10		91	9·539	3·592	32		
8	12		126	11·225	4·225	39		
9	14		170	13·038	4·908	44		
10	16		217	14·731	5·545	50		
11	16	f_1 0·915	36·6	6·213	5·685	53·5		
12	18		45·5	6·745	6·712	58·5		
13	20		57·5	7·583	6·938	66		
14	22		69·5	8·337	7·628	74		
15	25		96	9·798	8·965	87	9·706	
16	29		119	10·909	9·982	96	9·62	
17		f_1 0·915	96	9·798	8·965	87°	9·706	Continuous current.
18			123	11·09	10·15	98	9·656	

From the last two observations it appears that there is no sensible difference between the results with alternating and continuous current.

Comparison of Standard Resistances. 2nd Aug. 92.

Spiral of nickel plated manganin. 0.1Ω Compared with my Standard Legal ohm = 1·00028 Ω @ 16·9°c.

Balance at 100 for 99·5Ω on my standard @ 28·6°c against spiral @ 24·2°c

Result :- Res: of spiral 0·09732 Ω @ 24·2°c.

Spiral of nickel plated manganin. 0.1Ω compared with grid in series See p. 101

24·2°c

Test and readjustment of Edison Meter for Mr Brotherhood's house

The resistance of the strips = 0·09995 Ω @ 23°c.

Resistance of various pencils of graphite

Samples for bifocals

A.W. Faber #2.	12 Ω
"	17 Ω
HHH.HHH	77 Ω
HHH.HHH	82 Ω

Inductance Measurements Aug. 26th

Meter bridge, calibrated as follows:-

Arms of fine german silver or platinoid wire

45 cms.	= 10.076 ω	= 2.243 ω per cm.	90 cms + box	20.466 ω
41 -	= 9.405	= 2.293 ω . .	45 - + -	10.370 ω
86 -	= 19.499	= 2.267 ω . .	4 - + -	.947

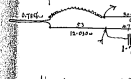
Accepted at 2.27 ω per cm.

Balance wire of manganin.

90.5 cms.	= 2.366 ω	= 0.026152 ω per cm.	100 cms + box	= 2.502 ω
50. -	= 1.239	= 0.024778 ω "	50 - + -	= 1.262 ω
46.5 -	= 1.127	= 0.024103 ω . .	3.5 - + -	= 0.136 ω

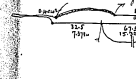
Accepted at 1.02465 ω per cm.

Soft iron wire doubled upon itself in one straight loop.



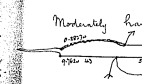
Res. of loop $0.7850\omega \times 1.7 \times 10.67 = 14.25 \times 10^3$ cms.
Length of wire 197.5 length of loop 98.8
Inductance per cm. of loop 1442.3 approximately
" " of wire 134
Diameter of iron wire 2.060, width of loop about 0.5.

Hard + ready iron wire doubled into a single loop straight.



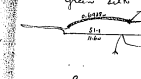
Res. of loop 0.4042ω
Inductance $0.4042 \times 2.95 \times 15.32 = 1.827 \times 10^4$ cms.
Length of wire 376 cms., of loop 188 cms.
Inductance per cm. of loop 97.1
Estimated " of wire 90.
Diameter of iron wire 0.156 cm. 2.5 cms distance of sides apart.

Moderately hard galvanized iron wire, doubled upon itself into a single loop.



Res. of loop 0.2827 ω
Inductance $0.2827 \times 3.5 \times 12.94 = 1.281 \times 10^4$ cms.
Length of wire 378 cms. of loop 189 cms.
Inductance per cm. of loop 67.74
Estimated " of wire 60
Diameter of iron wire 0.156 cm 2.5 cms distance apart.

Green silk lamp cord. 713 cms. long, wire connected at end.



Res. of loop 0.6938 ω
Inductance $0.6938 \times 18.1 \times 0.8 = 6.161 \times 10^3$ cms.
Inductance per cm. of loop = 8.642.

No appreciable change was discovered in the inductance of this cord, when instead of being left straight, it was coiled up on a wooden reel in 3½ layers.

The inductance balance in this last test was perfect. With all three iron wire loops, it was very imperfect, a mean guess could only be obtained.

The principal sizes of conductor used in American telegraphy are in iron # 6 B+S and #8 B+S.
in copper # 9 - - # 10 -

Log 1618 = 2089275
0.001313
2076672 1614·2

23·3
0·7 × 1614 = 113
11

No. of Obs.	Time	Current by Ammeter	Res. of Grid	P.D. on grid	Current by Potent.	Res. of Galvo coils	Res. added to wires	Ratio	Res. of wire
1	14·09	40	0·001618 Ω	1		2730 Ω	3810	2·396	3·893 X10⁻³
2	·25	80	@ 0°C.	0·58			4·110	2·505	4·071
3	·37	160	0·001611 Ω	0·282	173·5				
4	·45	"	(a 0°C.	0·279	171·7		4·210	2·542	
5	·47	"	0·001625 =	0·278	171·1		4260	2·560	
6	·50	190	@ 23·3°C.	0·326	200·6		4300	2·575	4·184
7	·55	140		0·323	198·8		4410		
8	15·0	188		0·323	198·8		4460		
9	·05	185		0·323	198·8		4500		
10	·10	186		0·320	196·9		4530		
11	·12	184·5		0·318	195·7		4560		
12	·15	231		0·391	240·6		4560	2·670	4·339
13	·20	231		0·390	240·0		4660		
14	·25	233		0·395	243·1		4780		
15	·27	230		0·386	237·5		4870		
16	·30	230		0·386	237·5		4920		
17	·35	230		0·386	237·5		4900		
18	·40	230		0·386	237·5		5060		
19	·42	260		0·356	237·5		5040	2·8446	4·625
20	·48	259		0·444	273·2		5180		
21	·53	261		0·436	268·3		5260		
22	·57	260		0·442	272·0		5390		
23	15·03	260		0·441	271·4		5420		
24	·05	260		0·441	271·4		5480		
25	·07	260		0·441	271·4		5490		
26				0·439	270·2		5490	3·016	4·893

Carrying Capacity of Simens Cable contd. (111)

The next sample tested was a 30' length of 80,000 circ. mil. cable of 12 for 2000 v. The length 909·5 mm. between pressure wires or 920 mm. between conductor extremities. The conductor is composed of seven wires stranded, each 0·276 in diam. (0·1087") = # 12 B.W.G., 11,951 c. mils = 83,167 in all. Area 0·059238 sq" The maximum strand diameter = 0·828 mm. Total 0·415716

The insulation consists of two coats of jute laid on in opposite directions and saturated in special compound. (T.C.?)

The diameter over the two coats = 1·374 0·546 0·273 0·109

" lead sheath = 1·693 Thickness of sheath = 0·15

Mass of the 30' = 12·02 kgm = 26·5 lbs. = 0·8833 lbs per ft = 1307 gms per m

" per mile = 46664 lbs. per kilometre 1307 kgms.

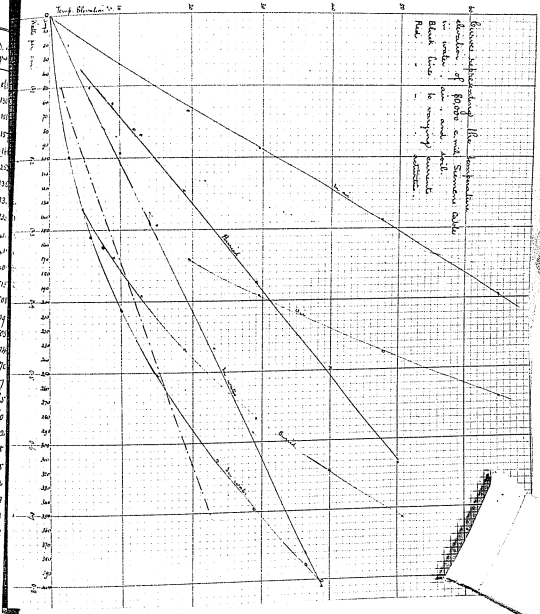
The length was stretched along the floor and connected in series with the large grid. Current was supplied from a continuous current transformer in the dynamo room, detivated from 500 volts. The current through the circuit under 3·15 volts pressure was 70 amp. representing 0·045 ω resistance which includes the transformer armature and connections.

Res. per cm	Resistivity @ 0°C.	$\frac{R}{r}$	Observation Temp. of air °C.	Temp. of wire °C.	C^2	Watts per linear cm.	Therms per linear cm.	Watts per sq. cm. surface	Temp. rise
3·9160 X10⁻⁴									
4·289 X10⁻⁴	1·792 @ 23°C	1·093	23·3	—	1600				23·5°C.
4·476	1·640 @ 0°C.	1·093	35·2	119	4400	28614·X10⁻²			
	0·972 cond.								
4·600		1·175	42·8	195	29,275	1·347 X10⁻¹			
4·770		1·218	52·7	294	39,204	1·870 X10⁻¹			
5·065		1·293	71·0	477	56,406	2·868 X10⁻¹			
5·380		1·374	88·5	662	73,441	3·951 X10⁻¹			

The low conductivity of this conductor (0·972) is perhaps attributable to its stranded form.

80,000 c.m.s. in inches

Mark No	Time	Res. of 1/2 cable	Res. read by Wheatstone	Ratio	Res. of 1/2 cable at 0°C	Cable	Res. per c.m.	Resistivity @ 0°C	$\frac{R}{r}$	Temp. of wire	Elevation of temp.	Amount Current	Pd.
1	15.35	2733.5	3940	2.441	0.001655 @ 25.3°C	0.003966	3.888 / 4.30540	1855 / 1.387	1.121	30°C.	-	30	0.05
2	·41							1629 @ 0°C					
3	·45		3990	2.4378				0.979 mds				90	0.15
4	·48		4010	2.4467								90	0.15
5	·51		4010	2.4467								90	0.15
6	16.18		4090	2.4976	0.004009	0.003966	4.405 - 4.456		1.133	32.9	2.9°	95	0.16
7	·23		4160	2.5422					1.146	35.9	5.9°	115	0.19
8	·33		4190	2.5533								200	0.33
9	·35		4190	2.5533								200	0.33
10	·38		4240	2.5869	0.004115	0.003966	4.521 -		1.163	40°.	10°	200	0.33
11	·40		4320	2.580								250	0.41
12	·53		4320	2.580								250	0.41
13	·55		4440	2.624	0.004492	0.003966	4.607 -		1.185	45°	15°	250	0.40
14	·58		4540	2.646								305	0.511
15	17.01		4520	2.693								305	0.501
16	·04		4530	2.657								305	0.501
17	·26		4600	2.693	0.004317	0.003966	4.744 -		1.221	53.5°	23.5°	302	0.505
18	·28		4665	2.706								332	0.570
19	·30		4670	2.708								336	0.576
20	·35		4690	2.715								335	0.565
21	·20		4680	2.712								335	0.565
22	·23		4780	2.768	0.004487	0.003966	4.8463 -		1.246	59.2	28.7°	335	0.560
23	·27		4860	2.778								370	0.620
24	·30		4880	2.785								375	0.633
25	·32		4890	2.789								375	0.635
26	·35		4940	2.807	0.004532	0.003966	4.980 -		1.281	67.2	36.4	375	0.622
27	·35		4960	2.814								385	0.653
28	·43	2748.	4960	2.814	0.004572	0.003966	5.024 -		1.293	70.0°	38.8°	385	0.644


Temp. Elevation in °C
Current in Amps
Resistivity
Curves showing the relation between Temp. Elevation, Current, Resistivity & Resistance of Cable.
Black lines = values taken from Table.
Red lines = values interpolated from curves.

To find the mean radius of a Twin cable for insertion in the argument $\log_{10}\frac{R}{r}$

The area of the triangle ABC = $r^2\sqrt{3}$

" " " quadrant A DEF. = $r^2(\sqrt{3}-\pi/4)$

$= 0.16158\ r^2$

Let $\pi R^2 = 7\pi r^2 + 0.16158\ r^2$

$R = r\sqrt{7 + 0.0332}$ $\quad R = r\sqrt{7 + 0.0625}$

$= 2.7417\ r$ $\quad = 2.7076\ r$

This value of R makes the area PAR = area RST

$r = 0.138 \therefore 2.7417 r = 0.3782$

$R = 0.6870$

$\log_{10}\frac{R}{r} = \log_{10}\frac{0.687}{0.3782} = \frac{\bar{1}.83646}{\bar{1}.57772}$

$\frac{0.687}{0.3782} = 1.817$ $\quad 0.25874$ $\quad \log = 10.0626$

$\frac{R}{r} = \frac{6.2832}{0.25874} = 10.026$

	4037020	
	3641187	
	395833	
	359416	
	36417	
	32826	
	3591	
	3282	
	309	
	287	
	22	

Carrying Capacity of Siemens cable contd.

The length tested in air on the preceding page was placed in the iron pipe, see p. 106, and the test repeated with water flowing along the wire surface, in the pipe.

	Potential current	C^2	Watts per Centimetre	Thermal for Centimetre	Temp. of water	Means	Temp. of air	$\frac{39}{H_2O_2}$	ρ	K	Feed water C.C. of H_2O per sec.	Thermal observed
11	38·77	1503.	6.55×10^{-3}	1.56×10^{-3}	30.2 Init. exit	29·8	30°	23·2°	6.726×10^{4}			46·7	
	79·98												
	95·36												
	96·60												
45	103·40	4692·4	4.270×10^{-3}	1.017×10^{-3}					1.035×10^{3}	3002)	0·000 3331	"	
29	155·1	24056	1.072×10^{-2}	2.552×10^{-3}					4.125×10^{3}	2434	0·000 4108	"	
	206·1												0·6 x 47
	206·1				29·5 30·0	29·9°							= 28·2
46	206·1	42,477	1.920×10^{-2}	4.571×10^{-3}					2.303×10^{3}	2303	1·000 4342	"	3.15×10^{-2} per cm.
	252·9												
	252·9												
19	244·8	63,457	2.923×10^{-2}	6.958×10^{-3}					1.513×10^{3}	2270	1·000 4405	"	
	316·8				29·6 30·5	30·2°							46 x 47
	312·6												= 70·7
	313·2												
24	310·8	97,220	4.660×10^{-2}	1.109×10^{-2}					9.687×10^{2}	2330	1·000 4424	"	0.64×10^{-2} per cm.
	353·2												22 x 47
	350·7												= 1034
	348·8												103·7
	347·6												
79	344·5	121,034	5.862×10^{-2}	1.396×10^{-2}	29·6 29·6	30·0°			7.214×10	2164	1·000 4621	"	1.467×10^{-2} per cm.
	398·0				29·8 31·4	30·6°						73·3	20 x 73·3
	390·7												1466
	390·7												
207	388·9	152,646	7.602×10^{-2}	1.810×10^{-2}					5.815×10	2117	0·000 4722	"	1.444×10^{-2} per cm.
	401·8				30·4 32·4	31·2°	25·0°						20 x 73
	401·8												1466
204	398·7	160,560	8.066×10^{-2}	1.921×10^{-2}					5.479×10	2126.	0·000 4720	"	1.426×10^{-2} per cm.

Carrying Capacity of Siemens Cable cont.

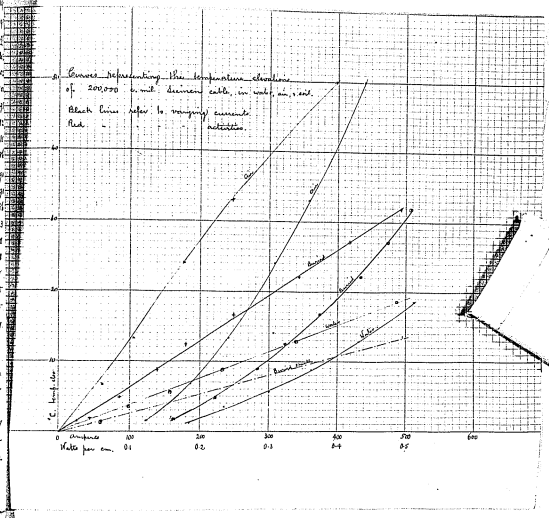
The next sample of cable was a 30' length of 208.000 c.m.(C.L.) 2050 v. #36.
The length between conductor extremities was 920.7
" weight of this length 18.6 Kilo = 41 Lbs.
" " = 20.2 grms. per cm. = 2.1357 Lbs per ft.
" " = 2020 kilos per kilometre = 7165 lbs per mile
" length between pressure wires = 906.2 cms. between ends of lead sheathing 903.2
" " left bayonet pressure wires for mains connection = 7 and 7.5 cms (estimated)
" strand consists of 19 wires each #10 B.S. 12 outside over 7 inside in opposite
" Diameter of each wire = 0.338 cm. = 0.1016" #10 B.S.
" Gross sectional area - - - = 0.05228 cm² 10,323 cir. mils.
" Total - - - of strand = 0.99334 cm² 196,150 cir. mils.
" Maximum diameter of strand = 1.361 0.536"
" Diameter over two coatings of jute soaked in compound 1.715 - 0.675"
" Thickness of insulator = 0.177 = 0.070"
" Diameter over lead sheath = 2.201 = 0.8665". Thickness of sheath = 0.813 = 0.096"
The cable was laid in a nearly straight line along the floor in 4 feet bends

Ref No	Time	Current by Ammeter #1 Range 200	Current by Ammeter #2 Range 100	Current by Ammeter #3 Range 100	Res. of yard	P.D. across yard	Current by Galvo.	Res. of Galvo unit	Res. added to yard to equate	Ratio
1	15.48	20	-	-	0.001625 Ω @ 23°C.			2736.5	130	0.9546
2	.52	60							120	"
3	.54	65				0.115	70.8		120	"
4	.55	120	75	150		0.202	124.3		120	0.9580
5	.58	120				0.205	126.2	2736.5	120	"
6	16.02	"				0.205	126.2	"	115	0.9596
7	.07	180	160	230		0.305	187.7		95	"
8	.12	180				0.305	187.7		85	"
9	.18	180				0.305	187.7	2736.5	75	"
10	.22	177				0.304	187.1		65	"
11	.24	"				0.303	186.5		60	0.9787
12	.28	240	215	270		0.391	240.6		40	"
13	.33	239				0.389	239.4		30	"
14	.36	239	220			0.390	240.0	2736.5	17	"
15	.38	240	"			0.391	240.5	"	15	"
16	.40					0.393	241.9		2	"
17	.48					0.393	241.9		1	1.00236
18	.50	302	285	320		0.510	313.9		22	"
19	.58	302				0.497	305.9		60	"
20	17.03	300				0.498	306.5		75	"
21	.08	300				0.498	306.5		81	"
22	.09	300				0.498	306.5	2736.5	90	"
23	.10	300				0.497	305.9	"	95	"
24	.14	"				0.495	304.7		105	"
25	.16					0.505	310.8		110	"
26	.18					0.500	307.8		115	"
27	.20					0.498	306.5		117	1.0428
28	.22	350	350	410		0.586	360.6		145	"
29	.26	347	345	410		0.582	358.2		155	"
30	.34	345	342			0.580	357.0	2736.5	185	"
31	.41	"				0.582	358.2	"	210	1.0768
32	.42	420	430	460		0.719	442.5			37° sheath
33	.47	420	420			0.716	440.7		285	"
34	.51	420				0.712	438.2	2736.5	345	"
35	.56	420	430	455		0.715	440.1	"	380	"
36	.57					-	-	2736.5	385	1.1408

Res. of Cable	Res. of cable per cm	Resistivity @ 0°C.	$\frac{R}{r}$	Temp. of cable	Elevation of bend of conductor	C^2	Watts per linear cm.	Watts per sq cm of sheath	Temps
0.0021851 @ 23.0°C.	1.687×10^{-6} Ω 1.711×10^{-6}	1.687×10^{-6} Ω 102.4 %	1.0 1.0132	23°C	0°				
r									
0									
0.0015872	1.7205×10^{-6}		1.098	24.5°C	1.5°	15.775	2.714×10^{-2}	0.003925	
0.0015902	1.755×10^{-6}		1.120	29.7°	6.7°	35.081	6.157×10^{-2}	0.008906	
0.001629	1.797×10^{-6}		1.147	36.2°	13.2°	58.322	1.048×10^{-1}	0.07516	
0.001629	1.870×10^{-6}		1.1932	47.0°	24.0°	94.556	1.768×10^{-1}	0.02557	
0.001750	1.931×10^{-6}		1.232	56.0°	33°	128.522	2.481×10^{-1}	0.03588	
0.001824	2.026×10^{-6}		1.306	72.8°	50°	193.952	3.967×10^{-1}	0.05737	44.6° sheath

200 000 emils. in water

Read Obs	Time	Rise of G	Rev added for balance	Ratio	Rise of gnd & body	Rise of cable	Rise for 1 cm cable	Resistivity @ 0°C	R t	Temp of wire	Elevation of temp	Current	Remarks
1	11h-24	27'9	96 b.l.p.		0.000854		1.5776×10⁻⁴			26.5°C.			
2	·29		76 "		0.24°C							110	8
3	·33		81 "									110	
4	·35		86 "					cond. 1.021				125	8
5	·41		86 "	0.96693		0.001576	1.731×10⁻⁴	1.561×10⁻⁴	1.727×10⁻⁴	1.1665	26.5°C.	0	155	8
6	·53		81 "										8
7	·57		79 "									210	8
8	12·03		74 "									205	8
9	·06		74 "	0.97740		0.001583	1.746 ×10⁻⁴	"		1.1111	27.7°C	1.2°	205	8
10	·10		71 "									205	8
11	·17		65 "									260	8
12	·21		65 "	0.9793		0.001583	1.756 "			1.1171	29.85	1.45°	255	8
13	·23		51 "										8
14	·30		41 "									320	8
15	·33		39 "									320	8
16	·37		39 "	0.9861		0.001603	1.768 "			1.1204	30.85	5.60°	320	8
17	·39		21 "										8
18	·46		11 "									385	8
19	·49		6 "									380	8
20	·52		6 "	0.99765		0.001620	1.787 "			1.1382	31.1	8·8°	380	8
21	·55		16 hours										8
22	16·00		24 "									452	8
23	·02		29 "									450	8
24	·05		31 "									450	8
25	·09		34 "	1.01227		0.001645	1.8152 "			1.1544	32.0	12·9°	450	8
26	·11		52 "										8
27	·16		76 "									520	8
28	·27		82 "									520	0
29	·28		89 "									525	8
30	·30		92 "										8
31	·32	27'6	92 "	1.03393		0.001680	1.8241 "			1.1795	43.75	18·6°	525	8
32														


Curves representing the temperature elevations
of 200,000 c. mil. insulated cable, in water, in emils.
Black lines refer to measured currents
Red " " " calculated
Centigrade
Watts per cm.

Taking d as 1·35
D - 1·715

$\log D = 0.234264161$
$- d = \frac{0.130333338}{0.103930303}$

$\frac{D}{d} = 1.2705$ $\log_{10} 1.2705 = 0.239$

$\begin{array}{r} 1.016740\eta \\ \underline{0.362241\varepsilon\gamma} \\ 1.378981\varepsilon\delta\varepsilon \\ \underline{0.798181\eta} \\ 1.420222\varepsilon\beta \end{array}$ 26316

Carrying Capacity of Simons Cable Sept. 21st

The length last tested was inserted in the same iron pipe as hitherto used, and the following measurements made with Heater flowing through the pipe.

Potential length C	Amperes Current	C²	Watts per linear cm.	Therms per linear cm.	Temp. of water C	Mean	Temp. of Cable	$\frac{W}{\pi L \theta_m}$	f	K	Feed water	Therms observed	
					cath. cab								
116·3	1"				26·2 26·1		20·8°C	$1{\cdot}277 \times 10^{-3}$					
					26·0 26·0								
121·3													
121·9					26·6 26·5								
121·9	121·9	14,860	$2{\cdot}584 \times 10^{-1}$	$6{\cdot}153 \times 10^{-3}$									
186·8					26·2 26·0	26·1							
185·9													
181·6													
193·4	185·1	34,242	$5{\cdot}981 \times 10^{-1}$	$1{\cdot}424 \times 10^{-3}$				$1{\cdot}818 \times 10^{-3}$	2·220	0·0001291			
235·1													
236·9					25·6 25·4	25·6							
237·5	236·5	55,932	$9{\cdot}826 \times 10^{-1}$	$2{\cdot}338 \times 10^{-3}$				$1{\cdot}126 \times 10^{-3}$	3·885	0·0002714			
301·5													
301·5					25·0 25·0	25·0	22·0						
299·1					25·0								
297·3	299·9	89,940	$1{\cdot}590 \times 10^{-1}$	$3{\cdot}785 \times 10^{-3}$				$6{\cdot}952 \times 10^{-3}$	3893	0·0002567			
361·8					25·0 25·0		23·0						
361·8													
361·8					25·0	25·0							
360·9	361·3	130,538	$2{\cdot}337 \times 10^{-1}$	$5{\cdot}564 \times 10^{-3}$				$4{\cdot}730 \times 10^{-3}$	4·162	0·0002403			
433·9					24·8 25·0		23·5						
429·0													
432·6					25·0	25·1							
433·3	432·2	186,800	$3{\cdot}341 \times 10^{-1}$	$8{\cdot}071 \times 10^{-3}$				$3{\cdot}258 \times 10^{-3}$	4·201	0·0002379			
515·2					24·6 25·7	25·2							
515·2													
512·1													
505·9	512·1	262,246	$4{\cdot}689 \times 10^{-1}$	$1{\cdot}158 \times 10^{-2}$	24·9 25·0	25·0	20·5	$2{\cdot}273 \times 10^{-3}$	4·193	0·0002385	70 c.c. per min.	0·8875 Therms per linear m.	

Test of the #12 B.S. cable on the floor of heating room.

Test No.	Time	Rise of T_2 coils	Rise added for balance	Ratio	Rise of cold junct.	Rise of wire	Rise of wire per cm.	Resistivity @ 0°C	$\frac{R}{r}$	Temp. of wire	Elevation of temp. of wire	Corrected current	TD on grid
							$\frac{\text{rise}}{\text{length}}$					amp.	
1	9.26	2735	14.41	0.9949	0.24932	0.014908	5.366 × 10⁻³	16.21 × 10⁻⁶ ohms per cm. cube	1.092	23°C	-	13	
2	.46		18.1	1.0066				16.37				15	0.930
3	.47		41	1.01499								16	0.937
4	.52		53	1.01938								18	0.939
5	.54		54	1.01974								18	0.939
6	10.03		57	1.02157								18	0.936
7	.12		63	1.02302		0.050433	5.517		1.123	30.5	7.5°	18	0.933
8	.14		93	1.0334								24	1.255
9	.20		103	1.03766								24	1.238
10	.28		121	1.04422								24	1.237
11	.32		128	1.0457								24	1.255
12	.38		125	1.04587		0.05153	5.640		1.1248	36.3	13.3°	24	1.231
13	.39		173									32	1.650
14	.46		269									32	1.645
15	.50		215									32	1.655
16	.52		221									32	1.665
17	.58		225	1.08228		0.05336	5.837		1.188	45.75	22.5°	31	1.666
18	11.00		273									37	1.932
19	.03		288									37	1.930
20	.05		305									37	
21	.10		320									37	1.918
22	.13		325	1.1188		0.05545	6.034		1.230	55.5	32.°	37	1.916
23	.20		398									43	2.222
24	.25		423									43	2.216
25	.27		433									43	2.206
26	.33		448	1.1638		0.05737	6.277		1.278	66.5	43.°	43	2.210
27	.40		550										2.432
28	.43		555										2.432
29	.46		568										2.452
30	.48		578										2.450
31	.51	2744	579	1.2117		0.05973	6534		1.330	76.5	55°.		2.466

Carrying Capacity of Siemens Cables contd. Sept. 6th (115)

Temp. Junct.	Potential C.	Mean C	C^2	Watts per linear cm.	Thermal per linear cm.	Calculated temp. of sheath	Temp. elevation of sheath	Convection per sq. cm. watts	Total convection per linear cm.	Radiation per linear cm.	Radiation per sq. cm. $\frac{\text{watts}}{\text{sq. cm.}}$	A_y	m.
23°.													
	18.66												
	19.00												
	19.05												
23.2°	19.05	18.94	358.72	1.879×10^{-2}	4.742×10^{-4}	44	21.°	2.9°	0.00507	0.01372	0.01730	0.00918	0.00155
	18.98			0.01971 0.00523 0.01743									
	18.92												
	24.24												
	25.11												
	25.09	24.73	611.57	3.145×10^{-2}	8.214×10^{-4}	60	30.5	7.5°	0.02260	0.0219	0.0219	0.00885	0.0089
	24.24			0.03145 0.0154 0.0269				6					
	24.93												
	33.47												
	33.37												
	33.57	33.576	1128.9	6.589×10^{-2}	1.569×10^{-3}	91	36.6	18.5	0.02362	0.04227	0.04227	0.01708	0.02784	2.3
	33.77			0.06634 0.02261 0.04427									
	33.80												
	39.19												
	39.18												
		39.03	1523.3	9.192×10^{-2}	2.212×10^{-3}	121	43.5	20°	0.0350	0.05792	0.05792	0.02341	0.0113	2.072
	38.91			0.09192 0.03320 0.05792									
23.5°	38.86												
	45.07												
	44.95												
	44.75	44.90	2016.0	1.265×10^{-1}	3.013×10^{-3}	154	54.1	27.6°	0.04183	0.07225	0.07225	0.03162	0.0169	1.975
	44.93			0.12652 0.04183 0.07469									
	50.13												
	50.13												
23.6°	49.73	49.914	2494.0	1.632×10^{-1}	3.886×10^{-3}	192	54.3	35.8°	0.05264	0.10058	0.10056	0.04064	0.0216	1.98
	49.69			0.1632 0.05264 0.11056									
	50.02												
	49.70												

Design for a powerful Heat Magnet. 8th Sept.

The winding space for this magnet is represented on the opposite page. With the partitions of copper ½" thick to increase the convective surface, the carrying capacity of the winding should be considerably augmented.

With #15 B&S. copper wire s.c.c. from 0.072" to 0.057", there will be 16 turns per layer and 11 layers in each partition or 176 turns. The length of the mean turn will be 22" or 1.83' so that the wire in each

block = 322·6' = 0·827 lb. @ 100°C. or 0·642 lb @ 20°C. = 5·065 lbs.
Or slab = 2580·8' = 6·619 lb. @ " " 5·136 " " = 40·520 "

The number of turns on the slab = 1408.

Filling up to the dotted lines with the same wire, 1⅜" × ½". There will be 16 layers of 16 turns = 256 turns per block, and the length of the mean turn = 23" = 1·918'. So that

per block = 491' = 1·259 lb @ 100°C = 0·9776 lb @ 20°C = 7·71 lbs. = 256 turns.
" slab = 3928 = 10·08 lb " " = 7·8208 lb @ " = 61·68 " = 2048 "

Test of a Thermo-electric cell 9th Sept. 92

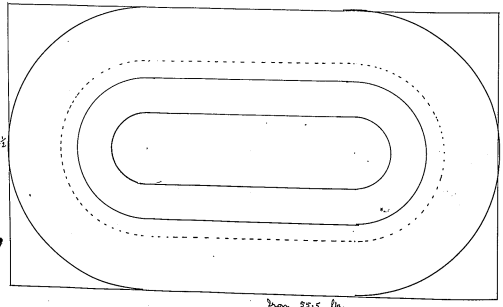
A dish of copper about 12·5 cms. in diam. and 7 cms. deep, riveted to a handle, was placed on a furnace. In the dish was placed a piece of copper oxide, and on this powdered caustic soda. The ~~whole~~ dish was then heated to a dull red heat, the soda melting, a lump of coke, exposing some 30 sq cms. of surface to the liquid, was plunged in the melted caustic soda, and supported in the dish but not touching the same. Wires were taken from the dish and from the carbon plate, to a Weston ammeter and extra res: with leads of which the following measurements were taken.

Leads 0.065 ω
Ammeter 0.007 ω — Simplex ammeter
Extra Res: 2·348 ω — Total without extra Res 0.072 ω, with 2·42 ω

This was observed for emf and int. res: readings.
On first dipping in the coke, a current of 0·5 amp was observed. This diminished and reversed. After reversal the current increased up to 1·5 amperes, without extra res: and 0·875 amp. with, making the EMF 0·32 volt, and the int. res: of the dish cell, 0·14 ω. This current was steady, at any one moment, but would vary with a change in the position of the coke plate. When the cell became red hot bubbling took place in the liquid, and the liberated gas finally ignited. It was probably CO. The EMF still continued under these conditions, but slightly diminished. It reached a maximum when the ebullition ceased.

On the following day tried a cell made up in the same dish and under the same conditions except that caustic potash was used in place of caustic soda. The potash melted much less readily. The best results gave 0·16 volt and 0·13 ohm. int. res: The caustic soda cell was decidedly preferable.

Plan ½



Cross section ½

Iron 99·5 lbs.
Fiber 1·34 "
Paper 39·5 "
Wire 14·16
154·50

Total weight when constructed 154·5 lbs.
" resistance " " 7·954 ω @ 24·6°C.
" number of turns " 2048

$\frac{100}{0.0993} = 1007$ $\frac{1.228}{1.007} = 1.220$

Tests of Storage Cells – Ernet – continued from page 93.

No of Test	Date	Charging current	Charge	Rest in circuit	Discharge	C	Charge Transfer	Charge Mean	Discharge Transfer	Discharge Transfer	Discharge Cells 3° & Cells 4 in parallel	
							Energy watts		Energy	Quantity watts	Energy	Quantity
1	16th Aug.	5 amps.	100·5		51·7		0·0845 0·0845	0·0895	0·0675	0·0675	48·3	55
2	18th		157·2		83·2		0·161 0·159	0·1160	0·070	0·107	78·6	87·7
3	19th		124·1		81·5		0·110 0·111	0·1105	0·072	0·108	80·9	82·0
4	21st		114·3		84·2		0·134 0·132	0·133	0·074	0·1014	83·1	85·3

Tests of a model Edison motor for Battery.

Resistance coil of field 0·085 ω
" " armature 0·23
" " motor 0·315 ω

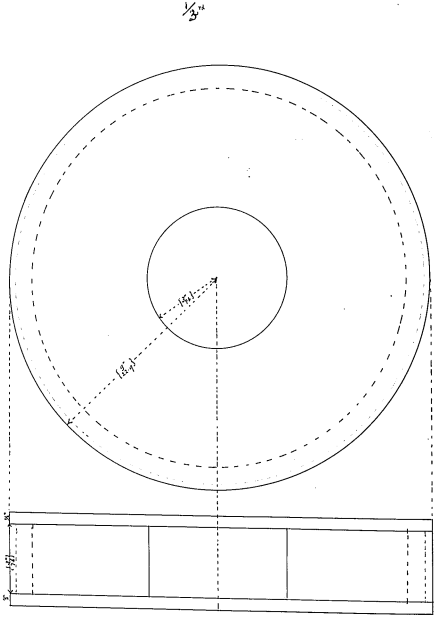
Clearance end entrefer, as constructed 0·015".
Speed running light, on one storage cell 900 rpm current 1·75 A.
" with four on 4 Eclande cells 1·4 volt at terms. 1460 rpm 2·32 A.

Porter motor.
Res. of field 0·314 ω
" armature 0·30 ω.
" motor 0·614 ω.

Speed, running with one four, on 4 Eclande cells. 1·99 volts at terms 470 rpm. 1·70 A.

After grinding down the armature surface of the Edison model 0·010" until the entrefer was 0·025", the speed increased to about 1100 rpm. and the current to about 2·0 amp.

Test of a model of the second 100 built by the Phonograph Works.
With new four whose blades are bent across a drum 18" in diam.
The line AB is a generating line of the cylinder on which the blade is bent.
The speed was 1220 rpm with one of these taken at random on 4 cells freshly set up, taking 3·14 amp.
The speed was 1360 rpm. with the same four on a motor whose entrefer had been increased (A above) from 0·015" to 0·025". current 3·5 amp.



Area of one side of cylinder	411.9 sq. ins.
Circumference of cylinder	71.92 ins.
Area of cylinder face	730.8
Both sides	823.8
Total surface	1554.6
Energy per sq. cm.	10 watts
Energy permissible	155.5 watts.

On the winding for a large drum magnet.

The core will be of wrought iron, and the flanges of cast iron.
The winding will occupy the roller up to within one inch of the rim.
The content of the space = 519 cubic ins. = 100 lbs. of wire roughly. allowing
150 watts at 1·25 amps. = 1·2 ω or 0·012 Ω 60°C = # 10 B.W.G.
The weight of the iron spool with axle and dogs is 104 lbs.
The wire adopted = # 11 B.W.G. 0·12" d.c.c. 0·136".
The body insulation is 0·020" fibre all round.
There should be 21 turns per layer. and 36 layers.
The mean diam = 11". Mean circ. 34·56" = 2·88' Mean diam 11·75" Mean circ. 3·076'
Total estimated turns = 756
Total estimated length = 2177' 2322
" " weight = 98 lbs. 101·5
" " resistance = 1·56 ω cool @ 20°C 1·785 ω warm @ 60°C. 1·547 @ 25°C 1·907 @ 65°C
Actual winding 756 turns in 37 layers averaging 20·5 turns per layer
Resistance 1·857 Ω @ 19·4°C.

Analysis of a Weston ammeter 15th Sept: 1892.

This is a 5 ampère meter marked No. 251.
The moment of the springs at half load — 3·5 amps. = 0·361 cm. gms. by 1st trial.
0·343 " " 2nd trial.
Mean 0·352 " "
at 5·0 amps = 0·704 " " (full load) 90°

This represents 2·816 cm. gms. or 27·62 dyne-cms. for one revolution or 2π.
The radius of the pointer extremity is 8·9 cms. (3·5")
" mean radius of the coil is 1·3 Mean length of one side 3·3.
The coil has 25 turns of wire, making 50 full passages, and has a
resistance of 0·56 ω @ 22°C., in circuit with a resistance of 0·170 ω.
The total resistance of the shunt path containing the coil is 0·690 ω
" resistance of the main shunt is 0·007 ω so that the saturating
current in the coil is 1/99 th of the main current, or 5/112 = 45 m/m
at full load.

The total length of wire in the field is 25 × 2 × 3·3 = 165 cms.

$H \times 5 \cdot 0 \times 10^{-3} \times 1 \cdot 65 \times 10^{4} \times 1 \cdot 35 = 690$

$11 \cdot 14 \times 10^{-1} H = 690$

$H = 6083$ say 600.

The polar surface is about 10 sq. cms. and the cross section of the magnet about 3 sq. cms. The intake about 0.22. The reluctance of each gap is about 0.022 making 0.044 in all. While 6000 lines are accounted for in the gap, the intensity in the magnet for this flux would be only 2000. The F.D. across each air gap would be 13·2 or 26·4 between magnet poles.

The resistance of the ammeter whose full load is 0·25 ampère is 0·030 ω and it would seem from these two instruments that Weston's shunt or main shunt resistance are $\frac{0 \cdot 035}{c}$ ω where c = ampère at full load.

The resistance of a 150 volt voltmeter is 16,000 ω, so that its full load current is 9·4 milliampères. The instrument began to be affected by the stray field from the #20 dynamo at some 8 feet distance.

for 2 bars buried at 87 diameters

No of Obs	Time	Resr. of Coils	Resr. added for balance	Ratio	Resr. of grid at Temp.	Resr. of wire	Resr. of wire per cm. ±.03%	Resistivity @ 0°C.	R/r	Temp. of wire	Elevation of temp. of wire from normal	Ammeter Current	P.D.
1	8·47	2705	792 high	0·7735	0·0493	0·03813	5·298×10	1597 (in bath for 107)	1·0495	23·75	-	16·5	0·87
2	·53		782										
3	9·05		780									15·8	0·82
4	·17		780	0·7764		0·03827	5·315 ·		1·0498	24·5	0·75°		0·79
5	·30		750									24	1·24
6	·30		742									25	1·29
7	·55		757	0·7815		0·03853	5·351 ·		1·106	26·23	2·5°	22	1·11
8	·05	2710	730									28	1·47
9	·22		720									27·5	1·42
10	·28		720	0·7[illegible]		0·03846	5·411 ·		1·1183	29·3	5·65°	27.	1·41
11	·31		685									33·5	1·74
12	·36		680									33·5	1·78
13	·42		677									33·0	1·71
14	·50	2715	676	0·8006		0·03947	5·492 ·		1·1330	32·8	9·05°	33·0	1·71
15	·58		620									40.	2·09
16	11·03		616									40	2·09
17	·08		613									40	2·09
18	·14		613	0·8167		0·04021	5·584		1·154	37·8	14·05°	40.	2·09
19	·17		540									45.	2·51
20	·22		532										2·38
21	·27		532	0·8366		0·04124	5·727		1·184	44·8	21·05°		2·31
22	·40	2720	440										2·07
23	·46		412										2·07
24	·45		402										2·07
25	·50		397										2·07
26	·55		392										2·07
27	·57		388										2·07
28	12·00		387	0·8753		0·04315	5·993		1·2388	57.5°	33.75°		2·97

Carrying Capacity of Siemens Babb. Supr. 9th

(119)

All four samples previously tested in air and water, were buried in the ground by the Galvanometer room wall, some 90 cms. away. The depth was 76 cms. The smallest wire is parallel to and distant from the wall. The others are 10 cms. further off in order of size. The intervals to attain horizontal distance of the first and last being 80 cms. The cables were bared, and wires soldered on 720 cms. from each other. 360 cms each from the center). In the largest size the distances was 720.5. This leaves 90 cms approx. of cable rising vertically to the surface at each end and also a pressure wire beside it. The trench was filled in with the red soil, but no large stones. There was no pavement placed above.

Potent. C.	Mean C.	C^2	Watts per 1 cm.	Thermo per 1 cm.	Calor. temp. of shutt	Temp. diff. of shutt	Watts per sq. cm. of shutt	Thermo per sq. cm. of shutt			Inverse Ratio of Res.	Temp. empirical
17·69											1·2923	
16·80	16·77	281·23	1.445×10^{-2}	3.56×10^{-4}			6.041×10^{-2}	1.438×10^{-3}				
15·82											1·2878	
25·19												
26·26	24·66	608·12	3·2574 n	7·746 n		·	1.315×10^{-2}	3.131×10^{-3}				
23·58											1·2794	
29·81												
29·81	29·48	869·07	4·703 ·	1.12×10^{-2}		8	1.900×10^{-2}	4.528×10^{-3}				
29·11											1·2657	
35·82												
35·61												
35·61	35·62	1268·71	6·755 ·	1.656×10^{-2}		·	2.811×10^{-2}	6.692×10^{-3}				
35·45											1·2490	
42·51												
42·55												
42·51	42·50	1806·25	1.009×10^{-1}	2.402×10^{-2}								
42·43					24·75	1°	4.078×10^{-2}	9.710×10^{-3}				
											1·2262	
51·31												
50·83												
50·27	50·80	2580·64	1.478×10^{-1}	3.519×10^{-2}	25°	3°	5.973×10^{-2}	1.422×10^{-2}				
											1·1958	
60·24	60·24	3628·86	2.175×10^{-1}	5.179×10^{-2}	25	8·5	8.788×10^{-2}	2.092×10^{-2}			1·1423	25·4°c.

log 0.009995 + 3.9979976
1.00233 , 0.001151
3.9996976 = 0.009943209
2721 + 587 : 2721 :: 3308 : 2721 · 3308 : 3.5195555
1.5185831
2721 : 3.4369724
2.8813896 0.012073 ∞

No. of Obs.	Time	Res. of Q. coils	Res. added for balance	Ratio	Res. of grid & limit:	Res. of wire	Res. of wire from	Resistivity @ 0°C.	R/r	Temp. of wire	Elevation of level of wire above normal	Ammeter current	Nom. grid
1	13·35	2673	1025	0·7227	0·11073	0·057725	1·128	1600	1·074	18·6°c		60	0·789
2	·38		1000				1·112 ×10⁻⁵	1719 ×10⁻⁹				-	0·800
3	·52		970									-	0·808
4	14·20	2680	965	0·7252		0·057896	1·233		1·093	23·25°	14·65"	-	0·812
5	·22	2680	910									75	0·822
6	·40		895									-	1·047
7	·53	2690	895	0·7253		0·057058	1·258		1·115	29·5	9·9"	-	1·036
8	·55	2690	805									1000	1·146
9	15·00		779									-	1·410
10	·10		760									-	1·410
11	·20		745									-	1·405
12	·50	2700	745	0·7237		0·057462	1·311		1·165	40·4	21·8"	-	1·402
13	·53	2700	670									120	1·679
14	16·02		630									-	1·684
15	·15		615									-	1·680
16	·33	2710	610	0·9163		0·057855	1·369		1·214	51·8	33·2"	-	1·663
17	·35	2710	522									145	1·987
18	·45		487									143	1·975
19	·52		467									142	1·962
20	·58		447									146	2·010
21	17·05		405									-	2·020
22	·14		395									-	2·020
23	·18	2715	395	0·8730		0·060514	1·464		1·298	71·0	52·4"	-	2·020
24	·20	2715	260									170	2·376
25	·29		220									-	2·360
26	·38		195									-	2·330
27	·48		170									-	2·330
28	·55	2717	167	0·9620		0·01137	1·579		1·400	94·8	76·2°c.	-	2·330

Carrying Capacity of Siemens Cable earth

(120)

14th Sept. 92

The sample of #6 B.S. Cable buried in the ground was next tested.
The resistance of the grid in multiple 0.012074 ∞ ohms.

156.6 diameter radius

Temp of Air	Potential C.	Mean C.	C²	Watts per linear cm.	Thermal per linear cm.	Cable temp. of sheath	Temp. elevation of sheath above normal	Watts per sq. cm. of sheath	Thermal per sq. cm. of sheath				Specific watts
	65·22												1·3834
	66·12												
	66·54												
	67·11	66·25	4389 ·	5.412×10^{-3}	1.209×10^{-3}	16·9	10·25°	0·65"	1.208×10^{-3}	2.878×10^{-3}			1·3601
	84·46												
	86·53												
	85·63	85·574	7317	9.206×10^{-3}	2.192×10^{-3}	7·5°	21°	2·14"	2.455×10^{-3}	4.892×10^{-3}			1·3327
	117·2												
	116·5												
	116·5												
	116·1												
	115·9	116·4	13,544	1.781×10^{-2}	4.241×10^{-3}	18·0	22·4	3·8"	3.975×10^{-3}	9.406×10^{-3}			1·2789
	128·8												
	139·2												
	138·8												
	137·4	138·5	19,182	2.626×10^{-2}	6.253×10^{-3}	26·3°	25·5°	6·9"	5.863×10^{-3}	1.396×10^{-2}			1·2251
	164·2												
	163·2												
	162·2												
	166·1												
	167·0												
	167·0												
	167·0	165·3	27,324	4.051×10^{-2}	9.526×10^{-3}	40·0	31°	12·4"	8.930×10^{-3}	2.127×10^{-2}			1·1935
	195·6												
	195·1												
	192·6												
	192·6												
	192·6	193·7	37,520	5.927×10^{-2}	1.411×10^{-2}	59·3°	35·8	18·9"	1.323×10^{-2}	3.149×10^{-2}			1·0614

Report of Heat Test on Siemens Cable, Vulcanite Compound

Cable

Length in Feet	Area C.M	Outside Dia	Core Dia	Thickness of Insulation	Thickness of Lead	% Increase	Correspondg to % increase in Temp
1150	1000000	1.745"	1.575"	.177"	.110	31.8%	15.11%

Pressure wire

				Resistance in ohms Cold	Hot	% Increase	Corresponding to % increase in Temp
450	6159	170"	.083"	.053"	1.24	1.56	25.5	122.5

1100 ft. of cable on drum balanced in air.
50 ft. " " with 710 load.

Table showing Volts drop in Cable at different periods of Test.

Time	Current Amperes	Volts Readings
10.00	1075.	5.12
10.20	1075.	5.22
10.40	1080.	5.33
11.00	1045.	5.38
11.20	1075.	5.70
11.40	1075.	5.79
12.00	1100.	5.96
12.20	1110	6.25
12.40	1075.	6.11
1.00	1075.	6.15
1.20	1075.	6.51
1.40	1075.	6.61
2.00	1075.	6.73

Temp of room at start 21°C
" " " End 22.00 = 72°7
" " out Side of Cable at Start 21°= 70°4
" " " " " " End 21°= 17°9

No current through P.W.
Insulation at start 1200 megohms
" " Hot 1 " "

W.S. Clark
J.G.S.

Measurements of Electro-osmose.

15th Sept.
After several preliminary and unsuccessful trials, adopted the following method of measurement.
Two porous cells of the dimensions indicated on the opposite page were connected in series. They were soaked in paraffin wax at their bases and rims, and were filled to a convenient height with $ZnSO_4$ solution in H_2O whose density was 1.054 @ 20°C. When superficially dried they were quickly weighed and replaced in their respective humbugs, containing the same solution up to as nearly as possible the interior level. Weighed zinc plates formed the electrodes, one in each humbug and one in each porous cell. A few drops of pure paraffin oil were added to prevent loss by evaporation. The current was from 126 volts through three cells and 3 120 volt lamps in series. After a noted interval of time, the porous cells were removed, their rims carefully lifted out with as little superfluous liquid as possible, their exterior surfaces gently rubbed dry, and their weights observed. The current was sent through the cells so as to lower the level in one and raise it in the other, so as to obtain a fair mean transfer.

No. of Obs.	Time	Interval	Weight of cells Before	Weight of cells After	Gain	Loss	Mean transfer	Amp. Hrs.	Weight of cells Before	Weight of cells After	Gain or Loss	Mean Transfer	Transfer per amp. hour
1	started 9.161		76.816	76.580		0.236			122.900	119.985	-2.915		
			57.030	57.650	0.620		0.442					2.968	11.35 grammes = 10.77 c.c.
		2.25 hrs.	66.265	68.648	0.383			0.320					
	stopped 11.56		64.640	64.630		0.010	0.196	0.2644	120.990	126.010	+3.020		
								0.1627					
2	started 13.165		57.650	57.985	0.335								
			66.630	63.739		0.891	0.613	0.534	119.325	115.940	-3.385	3.348	6.90 grammes = 6.546 c.c.
		4.35 hrs.	76.580	77.195	0.615			0.4583					
	stopped 18.09		66.648	68.118		0.534	0.575	0.1167	122.495	125.805	+3.310		
												Mean	9.129 / 8.658 c.c. per amp. hour

27th Sept.
Two similar cells were made up with distilled water only using clean zinc electrodes. The transfer in this case was much more rapid.

No. of Obs.	Time	Interval	Weight of cells Before	Weight of cells After	Gain	P.D.	res.	Current	Mean	qr.	Transfer per minute	Transfer per hour per amp.	Transfer per amp. hour
			gms.	gms.	gms.			amp.	amp.	Centimetre	gms		
1	15.24.00	300 min.	109.879	131.360	21.482	0.478	12.765	0.03722			0.071647	2.057	7.406 gms
2	.25.00					0.470		0.03682					
3	.26.00		107.956	118.510	10.554	0.460		0.03606			0.03518	1.011	3.640 "
4	.27.00					0.450		0.03525					
5	.28.00					0.440		0.03390					
6	.29.00					0.430		0.03035	0.03468	1044			3.1026

1875

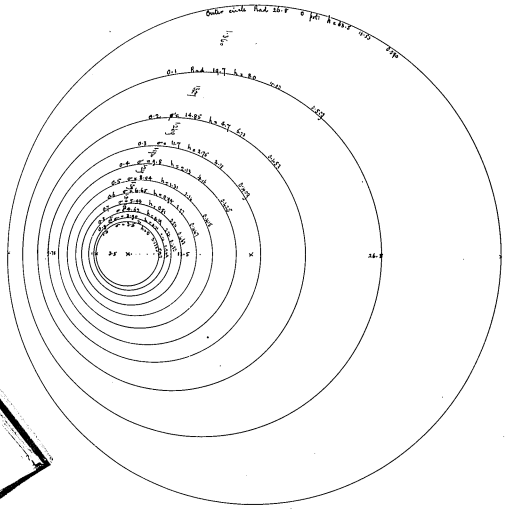
No. of Obs.	Time	Rec. of G. cock	Rec. added for balance	Ratio	Rec. of gas at temp.	Rec. of cable	Rec. of cable for 1 m.	Resistivity at 0°C	R_t	T	Elevation of temp. of hot wire	Ammeter current	R_{20} per yard
1	14.00	2724	2317	1.8506	0.006250	3.007×10^{-3}	3.007×10^{-3} / 4.176 × 10	16.28 000	1.0714	18.6°		70	0.130
2	.10		2317	1.8506	0.220	3.007 -	4.176 -			18.6°	0°	70	0.127
3	.12		2360	"								105	0.204
4	.25		2380									115	0.218
5	.35		2400									115	0.222
6	.42	2725	2410	1.8844		3.062 -	4.252 -		1.0914	23.4°	4.8°	120	0.225
7	.47		2460									150	0.278
8	15.00		2490										0.272
9	.12		2490										0.272
10	.19	2726	2490	1.9134		3.1095 -	4.318 -		1.111	27.6°	9.0°	155	0.272
11	.26		2520									180	0.332
12	.41		2550										0.318
13	.56		2570	1.9426		3.1562 -	4.383 -		1.127	31.5°	12.9°	180	0.318
14	16.00		2630									220	0.381
15	.15		2660										0.381
16	.27		2690										0.389
17	.42	2727	2695	1.9884		3.2244 -	4.4777 -		1.152	37.4°	15.8°	240	0.379
18	.45		2770									280	0.462
19	.58		2860										0.443
20	17.07		2885										0.449
21	.12		2890	2.060		3.3472 -	4.6449 -		1.196	47.6	19°	250	0.457
22	.18		2970									285	0.523
23	.26		3010										0.518
24	.35		3100										0.524
25	.38		3115										0.523
26	.42	2728	3115	2.142		3.2481 -	4.835 -		1.2444	55.7	40.1	285	0.522
27	.43		3210									322	0.581
28	.50		3265										0.575
29	.53		3320										0.573
30	.56		3330										0.571
31	.58	2729	3340	2.224		3.6114 -	5.019 -		1.291	69.5°	50.9°	322	0.578

Carrying Capacity of Siemens Cable contd. Sept. 18th

(122)

The 80,000 circular mil sample was buried in the trench was next tested. 45.5 diameter deep

Temp. of Air	Potential Current	Mean C	C^2	Watts per Linear cm	Therm. per Linear cm	Radius Temp. of sheath	Temp. Elevation of sheath above mean	Radius Temp. of sheath at the cable	Watts per sq. cm of sheath	Therm per sq. cm of sheath
21.5°C.	80.0									
	78.15	79.	6241	2.606×10^{-2}	6.208×10^{-3}			1.5°	4.963×10^{-3}	1.181×10^{-3}
	123.1									
	134.5									
	136.6									
	138.5	135.2	18279	7.774×10^{-2}	1.850×10^{-2}	19.4°	0.8°	44°	1.480×10^{-3}	3.523×10^{-4}
	171.1									
	167.4									
	167.4									
	167.4	168.3	28,325	1.223×10^{-1}	2.912×10^{-2}	21.4°	2.8°	6.2°	2.329×10^{-3}	5.546×10^{-4}
	198.1									
	196.7									
	195.7	196.5	38,612	1.692×10^{-1}	4.029×10^{-2}	23.0°	4.4°	8.6°	3.222×10^{-3}	7.673×10^{-4}
	234.5									
	234.5									
	233.9									
	233.3	234.1	54,803	2.404×10^{-1}	5.843×10^{-2}	25.4°	6.8°	12.0°	4.673×10^{-3}	1.135×10^{-3}
	284.3									
	284.9									
	282.5									
	281.3	283.2	80,202	3.520×10^{-1}	8.88×10^{-2}	29.3°	10.7°	18.3°	7.102×10^{-3}	1.691×10^{-3}
	321.9									
	318.8									
	322.5									
	321.9									
	321.3	328.9	103,234	4.991×10^{-1}	1.198×10^{-1}	34.5°	15.9°	24.2°	9.502×10^{-3}	2.269×10^{-3}
	357.6									
	353.9									
	355.7									
	355.7									
22°C.	355.7	355.7	126,522	6.356×10^{-1}	1.512×10^{-1}	38.5°	19.9°	31°.0	1.21×10^{-2}	2.879×10^{-3}
	356									



Potential	σ	ratio	Difference	h	$\frac{h}{\sigma}$	Mean	z
0·0	26·8	1:360	+0·135	15·53	0·580	0·477	0·103
0·1	29·7	1·327	+ 0·102	10·03	0·509		0·832
0·2	14·55	1·249	+ 0·1144	6·73	0·463		- 0·0244
0·3	13·7	1·194	- 0·031	4·78	0·409		- 0·068
0·4	13·9	1·219	- 0·056	4·16	0·3425		- 0·052
0·5	8·914	1·209	- 0·016	3·24	0·3615		- 0·062
0·6	6·65	1·211	- 0·014	2·97	0·447		- 0·030
0·7	5·149	1·183	- 0·037	2·64	0·463		- 0·014
0·8	4·62	1·185	- 0·040	2·22	0·1480		+ 0·093
0·9	3·90	1·130	- 0·095	2·14	0·564		+ 0·073
1·0	3·5			2·03	0·5214		+0·0243
					5·520		

Measurements in relation to the problem of eccentric cylinders. (123)

A sheet of ~~tin~~ brass iron 0·043 thick, was cut into a circle of 66 cms: in diameter. A strip 1·25 wide was cut from the center in a straight line to the circumference, making a slot in which the inner electrodes clamp bolt could travel. The disk was then tightly clamped between two massive brass plates fastened together by 12 bolts. The interior diameter of the rings was 53·6. These flat rings fed at four points formed the outer circular electrodes.

The inner electrode was a pair of short lengths of brass tube 7·0 in diam. one above and the other below the plate, in coaxial opposition. They were rigidly clamped together, and the upper tube was fed by two wires one at each side.

The pressure wire for the inner electrode was taken from a binding post screwed on to the sheet inside the brass tube. The

On the assumption that $V = A \log \sigma + B$

We have

1·0	= A log 26·8 + B	1·0 - -1·131 ×
0	= A log 26·8 + B	-B = -1·131 × 1·428
1·0	= -A log 7·646	B = 1·615
	= -A × 0·884	
	A = -1·131	

$\therefore V = -1.131 \log \sigma + 1.615$

σ = 3·9	$V = -1.131 + 0.591 + 1.615$	$= -0.668 + 1.615$	= 0·947	obsd 0·9.	0·047
σ = 4·62	0·6646	- 0·752	0·863	- 0·8	0·063
5·149	0·7396	0·836	0·779	0·7	0·079
6·65	0·8228	0·931	0·684	0·6	0·084
8·04	0·9053	1·024	0·591	0·5	0·091
9·8	0·9913	1·121	0·494	0·4	0·094
11·7	1·068	1·208	0·407	0·3	0·107
14·95	1·172	1·325	0·290	0·2	0·090
19·7	1·295	1·465	0·160	0·1	0·060
26·8	1·428	1·615	0·	0·	0

3·5 : 26·8 :: x : 13·5 + x

23·3x = 47·25

x = 2·03

In working out these results, they indicate some fundamental error pervading the whole series, which has therefore to be abandoned. See p. 126

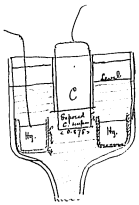
No of Obs.	Time	Rec. of G. cords	Rec. added to get for balance	Ratio	Rec. of grid at temp	Rec. of cable.	Rec. of cable for 1 cm.	Resistivity @ 0°C	$\frac{R}{r}$	Temp. of Cable.	Elevation of temp. of cable above room	Ammeter Current.	$\frac{A}{gal}$
1	8.25	2694	1245	0.6841	0.00855Ω @ 22°	1.1185	1.534 $\times 10^{-3}$					invisible	0.471
2	.40		1245									"	0.110
3	.55	2696	1235			1.1186×10^{-3}	-						0.102
4	9.00		1245									"	0.120
5	.15	2698	1245	0.6842		1.112	-					"	0.121
6	.22		1242									"	0.237
7	.30		1240									"	0.239
8	.42		1240									"	0.238
9	.52	2700	1238	0.6856		1.114	1.546					"	0.235
10	10.00		1220									"	0.200
11	.05		1215									"	0.333
12	.10		1215									"	0.333
13	.23	2702	1210	0.6906		1.122	1.557					"	0.220
14	.28		1210									"	0.409
15	.30		1200									"	0.295
16	.47		1187									"	0.400
17	11.00	2704	1200	0.6927		1.126	1.563					"	0.209
18	.05		1195									"	0.471
19	.25	2706	1180	0.6964		1.132	1.571					"	0.472
20	.27		1170									"	0.567
21	.32		1158									"	0.562
22	.48		1135									"	0.557
23	.53		1135									"	0.557
24	12.18	2708	1135	0.7024		1.145	1.589					"	0.557
25	.20		1130									"	0.648
26	.35	2710	1085	0.7112		1.1605	1.611					"	0.635
27	13.00		1065									"	0.704
28	.08		1050									"	0.700
29	.10		1030									"	0.740
30	.16		1020									"	0.740
31	.30	2711	1012	0.7281		1.183	1.642					"	0.730
32	.35		1000									"	0.784
33	.48		990									"	0.785
34	.58		967									"	0.778
35	14.10		960									"	0.770
36	.15	2711	960	0.7385		1.200	1.666					"	0.770

Carrying Capacity of Siemens Cable contd.

(124)

The 200,000 cm. mile sample 720.5 cms. long was next heated, in the trench.

Temp. of Air	Potential. current	Mean C.	C²	Watts per linear cm.	Thermo per linear cm.	Radius temp. of shield	Temp. elevation of shield above room	Cable temp. above conductor	Watts per sq. cm. of shield	Thermo per sq. cm. of shield			Summary ratio of exts.
													1.46618
													"
													"
													1.46614
													"
													"
													"
													"
													1.46585
													"
													"
													"
													1.46478
													"
													"
													"
													1.46437
													"
													1.4360
													"
													"
													"
													"
													1.4191
													"
													1.40034
													"
													"
													"
													1.3733
													"
													"
													"
													1.3541



Particulars of McKenna and Weed Edisontype Meter

This meter was examined in Allegheny City Pa. on the 22nd Sept. Several instruments were exhibited, but one in particular that had been in operation for several months. The load consisted of seven 50 cp lamps equivalent to 14 ordinary 16 cp each taking 0.85 amp. so that the total current was nearly 6 amp. The shunt consisted of two wires 0.035" in diam: G.S. in parallel and 34" = 2.833'. The res: of this wire being 0.198 ω per ft: = 0.1 ω per ft duplicate or 0.283 ω in all. With the meter intended for 10 amp, this would mean 2.8 volts drop at full load. The spool in circuit with the shunt coil had 11' of G.S. wire 0.010" = 11 × 2.4 = 26.4 ω res: The solution employed is water containing 5% by weight of HNO_3 and 5% Mercuric nitrate.

Heat tests with iron bobbin detailed on page 118.

The resistance of the coil was 1.857 ω @ 19°C

A current of $\frac{0.993}{0.09937}$ amp. was delivered through this coil for six hours.

The temperature of the surrounding air was then 21.4°C.

The temperature on the brass boss of the coil, on top, was 58.5 F.

" " at center of the coil on the vertical side, 61 and 60.2

The mean temperature of the coil surface would probably be 60°C.

" " " elevation 38.6°C.

" resistance of the coil @ 0°C. would be. 1.857 ÷ 1.198 =

" " " " @ load was 1.868 Ω

" temp: elevation for 1.298 = 62.7. = mean temp. of wire.

Current = 9.9925 amperes. C^2 = 98.51 C^2R = 186.5 watts.

Surface including ends 1600 sq: cms. = 0.1166 watt per sq: cm.

8.578 sq: cms per watt.

The entire surface of the drum was coated with japan varnish. The resistance at 21.8°C. was observed to be 1.863 ω. The insulation 120 Ω

A current of about 5 amperes was passed through the coil from 10.30 to 23.0 o'clock. At that time the current was $\frac{0.4925}{0.09937}$ = 4.956 amp.

The P.D. on the drum 7.932 volts. The energy in the drum by this

= 39.52 watts

= 0.02407 w per sq: cm

= 41.54 sq: cms per watt.

The temp. of the air was 20.5° C. at the time.

The temp: on top of coil = 29.8°C

" " " side = 30.0 °C at center. } Mean temp. 30°C

" " " elevation 9.5°C.

The res: of drum by PD = 1.634 Ω

" " " bridge = 1.645 ω

Mean = 1.64

Ratio = $\frac{1.64}{1.863}$ = 1.084 = 12.6 °C.

200,000 c.m.l. section bunch 314·5 diameter

No. of Wire	Tenns	Res. of 1 mile	Res. added for balance	Ratio	Res. of pilot at temp.	Res. of cable	Res. of cable per cm	Resistivity	R/r	Temp. of cable	Extension of cable by temp.	Corrected Current	P.D. per pair
1	13·20	2731	930	0·7446	0·0016252 @ 22°C.	1·2124x10³	1·6122x10⁻³	1·89 x10⁻⁶ ohms per cm cube	1·072	18·1°C.		82	0·192
2	·31		930									82	0·198
3	·45		930	0·7446		1·2122x10³	1·6122x10⁻³		1·072			82	0·159
4	·48		920									1344	0·216
5	·52		915									1344	0·215
6	14·05		907									1340	0·264
7	·16		905	0·7510		1·2120x10³	1·6093x10⁻³		1·079	19·8°	1·7°	1344	0·264
8	·18		885									209	0·205
9	·30		880									200	0·359
10	·41		875									200	0·364
11	15·06		865	0·7505		1·2334x10³	1·7128x10⁻³		1·0917	22·95°	4·85°	200	0·364
12	·10		830									260	0·465
13	·20		825									260	0·466
14	·42		812									262	0·466
15	·56		810	0·7712		1·2533x10³	1·7394x10⁻³		1·1054	27·0°	5·9°	262	0·465
16	·56		800									300	0·520
17	16·09		775									295	0·518
18	·24		775									300	0·530
19	·37		765									300	0·523
20	·48		765	0·7812		1·2695x10³	1·7624x10⁻³		1·123	30·5°	12·4°	300	0·521
21	·52		750									350	0·613
22	·65		730									350	0·610
23	17·80		710									350	0·610
24	·13		710	0·7936		1·2901x10³	1·7901x10⁻³		1·141	34·75°	16·7°	350	0·608
25	·15		680									400	0·710
26	·22		660									396	0·706
27	·29		640									396	0·705
28	·31		640	0·8100		1·3168x10³	1·8268x10⁻³		1·1614	40·2°	22·1°	396	0·705
29	·33		620									440	0·775
30	·40		615									438	0·775
31	·45		590									435	0·760
32	·47		580	0·8247		1·3140x10³	1·8200x10⁻³		1·1852	45·2°	27·1°	440	0·770
33	·48		570									-	0·800
34	·52		550									"	0·825
35	·55		540									"	0·822
36	·57		535									"	0·827
37	18·00	2727	525	0·8387		1·3363x10³	1·8542x10⁻³		1·2066	50°	31·9°	"	0·827

Carrying Capacity of Siemens Cables. Sept. 26th

(124)

Temp of air	Potential current	Mean C	C²	Watts per 1cm cm.	Thermal res. per 1cm cm.	Radius incl. of sheath	Temp. elevation of sheath above air	Radial fall of sheath below air	Watts per sq cm of sheath	Thermal res. per sq cm of sheath			Increase watts of res.
22°C	87.4												
	91.1												
	92.3	90.3	8154	0.01371	0.0032644			0.5°	1·983x10³	4·720x10³			1·3406
	164.9												
	163.1												
	165.5												
	162.5	164.0	26,929	0.04558	1.085x10³	1·4°	-	1·7°	6·892x10³	8·869x10³			1·3315
	218.5												
	220.9												
	224.0												
	224.0	222.1	49,328	0.07448	2.011x10³	1·9.75°	1·68°	3·2°	1·222x10³	3·248x10³			1·3168
	286.1												
	283.1												
	283.1												
	291.9	283.6	80,429	0.1399	3·331x10³	2·1.7°	3·6°	5·3°	2·023x10³	4·817x10³			1·2967
	320.0												
	318.8												
	326.2												
	321.9												
	320.7	321.5	103,362	0.1821	4·335x10³	2·3.6°	5·2°	6·9°	2·633x10³	6·269x10³			1·2802
	377.2												
	375.4												
	375.4												
	374.2	375.5	141,000	0.2504	6·055x10³	2·5·15°	7·05°	9·6°	3·650x10³	8·689x10³			1·2600
	436.9												
	434.4												
	433.8												
	433.8	434.7	188,964	0.3351	8·216x10³	2·8·1°	9·0°	13·10°	4·991x10³	1·188x10⁴			1·2384
	476.9												
	475.1												
	467.7												
	473.9	473.4	224,107	0.4168	9·926x10³	2·9·35°	11·25°	15·85°	6·027x10³	1·435x10⁴			1·2125
	492.3												
	509.6												
	509.6												
	509.0												
22°C.	509.0	509.4	259,468	0.4809	1·149x10³	3·1·35°	13·25°	18·60°	7·100x10³	1·691x10⁴			1·1923
	511.2												

Measurement of Power absorbed by Edison Battery Fan Motor.

27th Sept.

The motor was mounted in the boat, and the driven by a small Potter motor outside. The torques necessary to run the Edison motor with & without brushes on, and with or without field excitation were then observed.

No. of Obs.	Condition	Balance	Moment	Moment × 6·165	Energy per rev. (ergs)	Activity for 1200 rpm. (watts)	Loss in axle friction (watts)	Loss in brush friction	Loss in magnetic friction
1	Brushes up	50/00·4	20	1·233 $\times 10^5$	0·01233	0·247	0·247		
2	Brushes down	1·4	70	4·315 "	0·04315	0·863		0·616	
3	Field & Fan 3	2·3	115	7·09 "	0·0709	1.42			0·554
4									

These tests were repeated in a different way by mounting on the shaft of the Edison motor, a pulley 1·55 ins. in radius. The weight that had to be placed in a bucket suspended over the pulley was noted as soon as rotation was produced under various conditions.

No. of Obs.	Condition	Total Wt (Lbs)	Moment (ins-grms)	Moment × 6·165	Energy per rev. (ergs)	Activity for 1200 rpm. (watts)	Loss in axle friction (watts)	Loss in brush friction	Loss in Magnetic friction
1	Brushes up	65 *	100·8	6·21 $\times 10^5$	0·0621	1·24	1·24		
2	" down	115	178·2	1·098 $\times 10^6$	0·18	2·2		0·96	
3	1 lb = 0·531 - 5	125	193·8	1·195 "	0·12	2·4			
4	2 " 10 "	137·5	213·2	1·314 "	0·13	2·6			
5	3 lb 1·54 "	150	232·5	1·433 "	0·14	2·8			
6	4 " 1·98 "	150	232·5	" "	0·14	2·8			
7	5 " 2·41 "	154	239	1·474 "	0·15	3·0			
8	6 " 2·84 "	161	249·5	1·538 "	0·15	3·0			0·80
9	9 " 4·28 "	197	305	1·88 "	0·19	3·8			
10	12 " 5·68 "	219	339·4	2·092 "	0·21	4·2			
							Total 3·0		

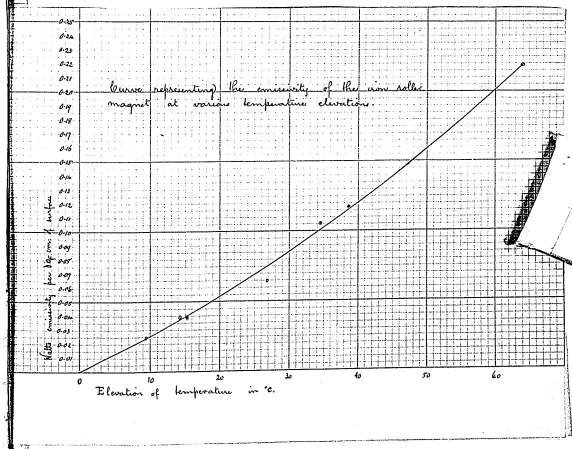
The second table gives starting frictions, the first running frictions. This accounts for the differences between their results.

A fan motor was set to work upon 10 cells of P Edison-Lalande battery which had been set up and in use for some little time.
The test started at 1¼ volt on the 26th Sept, and the fan stopped at some time during the night of the 2nd/3rd Oct: say 6 days 12 hrs, in operation = 156 hours or perhaps 468 amp. hrs.

* A three fan motor on the 6th October had a smaller commutator, the diameter being reduced ⅛". Tested by the same pulley on the shaft, the starting moment with brushes up was 95 gms × 1·55 and with brushes down 115 gms × 1·55.

The battery was refreshed, and the fan again started. It ran for 120 hours continuously from 1¼ volt on the 4th Oct. to 13 volts on the 10th.

No. of Obs.	Date	Strength of current.	Deflexn. on sides	Deflexn. on finishing	P.D. Potent.	Res.	Resistance by Resist. coils	P.D. on shunt by Potent.	Res. of shunt but by Potent.	Res. of shunt by bridge but	Res. of shunt by bridge wire	Res.
1	Sept. 24th	12 Bm			0·993	0·09937	9·9925			1·868	1·8570 @ 14·4°C	1·302
2	" 25th	12·5 "			0·34825	"	4·856	7·932	1·6314	1·6465	1·6446 @ 18·8°C	1·131
3	" 27th	9· "			0·940	"	9·460	17·829	1·885	1·882		1·301
4	" 29th	12· "			0·750	"	7·546	13·977	1·851	1·795		1·241
5	" 30th	12· "			1·2446	"	12·52	27·94	2·231	2·175		1·501
6	" 28th	13·			0·605	"	6·09	10·37	1·703	1·723		1·192
7	"											
8												



Temperature Elevation of Roller Magnet contd. from p. 125 27th Sept.

Current of about 10 amp: maintained through magnet from 9 a.m. to 1 p.m.

P.D. on magnet at 18 cells 17.829 volts

" " 0·1 m spiral " " 0·940 " (·0099377)

Current through circuit 9·460 amp.

Resistance of drum by P.D. 1·885 Ω

" " " bridge 1·882 Ω

Temp: of surrounding air 19·5° C.

" " top of cover 53·0° C.

" " centre of vertical side 55·2

Mean temp: of surface 54·1° C

" elevation of " " 34·3° C.

Energy in drum. 168·7 watts

" per sq: cm: 0·1054 " per sq: cm.

Surface per watt energy. 9·486 sq: cms: per watt

Nos. of element by bridge wire	Ω	Temp: of spiral	Temp: of air	Temperature on drum at sides	Temperature on drum at periphery	Mean Temp: elevation	C^2	C^2R energy per cm:	Energy per sq: cm: of surf:	Mean Temp: of copper by bridge	Temp: Elevation per watt per sq: cm:	Emissivity per °C temp: elevation watts	
1													
1.357	1·392	28·3	21·4°	60·6°	55°5	38·6°	98·51	186·5	0·1166	49.7°C.	331°	0·00302	Johnson
2 (14.46.5		25·5°	20·5°	39·0°	29·8°	9·4°	23·58	38·82	0·02407	34.°C.	3905	0·002662	Schumann
1.384	1·431	30·0°	19.5°	55·2	53·0	34·6	89·149	168·7	0·1054	72·8°	329·3	0·003046	"
1.241		39·6	18·6	46·3	44·4	26·8	56·934	102·5	0·06348	58·0°	418·2	0.002391	"
1.521		25·0°	20·2°	36·5	31·2	64·0°	156·75	324·7	0·2186	125·0	292·3	0·003345	"
1.192		25·3°	21·4°	35·5	35·5	14·2	37·09	63·14	0·03965	46·7	358·1	0·002792	"

Measurements of Electro-osmose cont. from p. 121.

27th Sept.

The same two porous cells were used again in distilled water.

No. of Obs.	Time	Interval	Res. in cell.	Rheo res.	Current	Mean Current	Weight of cells.		Transfer	Transfer per amp.	Transfer per coulomb	Transfer per coulomb
					amps	amps	#1	#2	gms	gms	gms	
1	17.01.00		12.65Ω	0.211	0.01668		106.702	108.742				0.0646
2	.02.			0.206	0.01629							
3	.03.			0.209	0.01652				6.183gm	4.50.0	1.0715	3.1858gm
4	.04.			0.2055	0.016248							
5	.05.			0.199	0.01573				10.978gm	799.0	1.902	6.850
6	.06.			0.187	0.014479							2.1756
7	.07.			0.177	0.011400							0.0.0
8	.08.	420secs		0.166	0.01313		107.680	102.559				
					0.123 61		10.978	6.183				
9					0.013 76							

The sp. res. of the water used in this test was then measured. An empty drill was filled to a depth of 8.35 cms. with distilled water. Two concentric electrodes were employed, one of 18.2 the other of 41.8 mm diam. with a pressure of 12.8 volts on the bath the current was $\frac{1.583}{61.82} = 0.02561$). The current per cm. of depth = 0.003067 ampere. With 128-2 = 126 volts the res. = 41,080 ω.

$$\frac{\rho}{2\pi} \log \frac{R}{r} = 41,080 \quad \therefore \rho = \frac{6.283 \times 41,080}{\log_e 3.791} = \frac{6.283}{1.3326} \times 41,080 = 192770$$

Sp. Res. = 194,000 ω per cubic cm.

Hookham's empirical formula for permanent Magnetic Circuits.

At pages 187-189 Vol 27 Phil Mag. 1889. Hookham gives an empirical relation for stable permanent magnetic circuits of hard steel. If l be the length of the air gap, A its area, L the length of the iron circuit, a its cross section

Then $\frac{A}{L} \geqq 70 \frac{a}{C}$.

From this $\frac{L}{A} \leqq 0.0143 \frac{l}{a}$

But $\frac{L}{A} = \mathcal{G}$ the reluctance of the airgap, so that this reduces to

$$\mathcal{G} \leqq 0.0143 \frac{l}{a}$$

On the Determination of the sheath temperature of a buried cable in air

If T = interior temp. of conductor (elevation)
τ = exterior " " sheath (elevation)

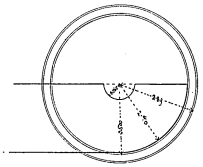
Then $\frac{V - v}{W} = \nu(\omega R + c)$ where τ = thermic resistance of insulator
θ = circumference of sheath
ω = coeff of radiation for surface
R = radiation (many) for 1°c for sq cm in watts
C = convection " " " per linear cm.

$$\nu(\omega R + c + \tfrac{1}{\tau}) = \frac{V}{\tau}$$

$$\nu = \frac{V}{\tau(\omega R + c + \frac{1}{\tau})}$$

$$= \frac{V}{1 + \tau(\omega R + c)}$$

Full sized plan of disk.



External Diameter of Disk	= 2.25" 5.72
Int. - of rubber ring	= 5.00
Outer Radius of pole face	= 2.46
Inner - - - -	= 0.565
Polar area - or semicircle	= 9 sq.cms
Allowing 1 mm. fringe all round	= 10.26 -
Outside	= 0.16 cm.
Reluctance of gap	= 0.0156
Number of turns in wide	52
- - wire	= 50
Diameter - -	= 0.010" d.s.c. 0.013" s.c. 20 B&S.
Mean length per turn	= 0.5'
Total length of wire	= 25'
res. of wire	= 2.60 ω by measurement 2.70 ω.
Length under magnetic force	= 2.5 x 2.0 = 5.0 cm.
Mean radius of action	= 1.53 cms.
Weight of disk wound	= 8.8 gms.
Cross section of magnet	= 2.67 sq.cms.
Mean length of Mag: at	= 37.5 cms.
Demagnetising force	= 20.6/37.5 = 5.6 lines per sq.cm. = -H.

With the two phosphor bronze springs employed on the machine on the 30th Oct. the moment = 0.9025 cm. gms. at 65° = 280.006942 cm. gms. per degree of deviation.
0.039239 give 36.6" so that temp: 91.8° = 63.71 cm. gms. = 2.26 62500 dm. degrs
= 125,000 cm. degrees.

Trials of first model Edison Ammeter. 28th Sept.

(130)

A current of 0.1081 amp: produced a deflection of 66.8° = 618° per amp.
- - 0.0781 - - - - 48.3° = 618.5° - -

A moment of 0.786 gms x 1.148 = 1.163 cm. gms. produced a deflection of 71.5°. .016266
- - - 0.385 - x 1.88 = 0.7237 - - - - - - 63: .01683
- - - = 0.01655 - - - - - - - 1° 0.01651
= 16.23 cm. degrees - - - - - - 1:

The moment for 10 amp = 6181.5° x 100,320 cm. degrees.
= 44.2 128 cm. degrees for each wire
= 20.062 - - - - cm. of wire
= 13/05 degrees per cm. of wire.
Mean field = 1310 C.G.S. lines per sq. cm.
Total useful field = 13,455 - - -
Useful flux through magnet = 4.935 - - - - - -
P.D. across gap = 24.206 20 amps per pole.

The steel springs were taken out and replaced by spirals made up from phosphor bronze wire. The instrument was then recalibrated with the following results.

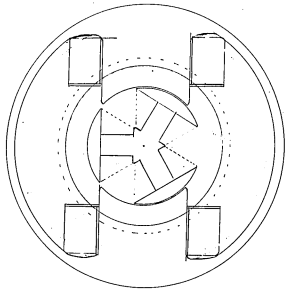
No. of Obs.	R. of fixed coil in ohms	Lamps in ckt. with 120 volts	P.D. across	Current	Deflection	Moment per 1° of deflection	Weight		Mean	.125 Amperes
1	12.66	2 λ	2.277	0.1799	124.5°	1.445 x 10⁻³	12	17.340		
2		3 λ	1.450	0.1145	85.5°	1.339 -	9	12.051		
3		4 λ	1.064	0.08404	63.0°	1.334 -	6	8.004		
4		5 λ	0.820	0.06477	48.0°	1.349 -	5	6.745		
5		6 λ	0.668	0.05277	39.0°	1.353 -	4	5.412	1.3767	0.17205
							34	49.552		

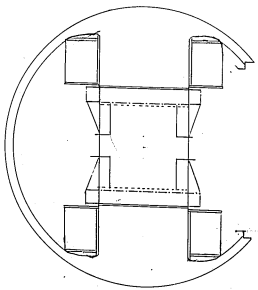
In order that 125 shall indicate 0.250 amp. the multiplying power of the shunt must be 1.453. The resistance of the instrument is 3.962 ω @ 20.5°C.
The shunt must be 3.962/0.453 = 8.746 ω.

Particulars of the #2 Phenoplex Coil as recently constructed at Silverlake

Rubber flanges 2 5/8" x 2 5/8".
Tube of hard rubber 3/4" ins. 7/8" outside diam.
Inter flange 3 7/8".
Core wire 7" long. #18 Brs. wire 0.04103".
Weight of core 114.7 gms = 0.324 lbs = 5.2 ozs.
Length of wire in core 5'8.0" = 100 wire
Winding 17 layers of #20 B&S. d.s.c. 0.035" to 0.038" x 96 turns = 1632 turns.
Outside diam: 2 1/4".
Coil kept incubated with paper.
Weight of wire in coil 2.187 lbs.
Length - - - 669' = 5.63 x 120°C. X
Mean diam: 4.91" = 0.41' = ϕ

Full size Sections.





Windings Field: 11 oz. # 15 B.W.G. d.c.c.
Arm: 2¼ oz # 20 B.W.G. or 19 B.S. d.c.c.

Design for a Spherical Shell Battery Fan Motor.

Power	=	2 watts.		
Battery required	=	3 Lalande cells		
EMF	=	2·0 volt		
Current	=	2·0 amp.		
Res: of battery	=	0·1 ω		
Drop in -	=	0·2 volt		
- leads	=	0·3 -		
PD at motor	=	1·5 -		
EMF of motor	=	1·2 .		
Speed - -	=	2100 rpm: = 35 rps.		
Type of motor		spherical with glass window.		
External diameter	=	4·0"		
Internal - of shell	=	3·75"		
Poles		two, square, 1·275" sq: = 3·24 cms × 3·24		
Polar bore	=	1·695"	4·25	1·626" manufactured
Armature diam	=	1·645"	4·18	1·581" manufactured
Face angle	=	78°.		
Side of bore equilateral Δ	=	0·5".	1·27	
Breadth of annular bit	=	0·3".	0·76	0·305" 0·775
Length - - -	=	0·93".	1·41	1·00 2·54
- - - face	=	1·625"	4·13	
Breadth - - -	=	1·025".	2·60.	
Actual Surface of one limit plate	=	2·85 × 3·4 = 9·68 sq: cms.		2·55 × 3·65 = 8·93
Reluctance of gap (angle)	=	0·004		
Entefer	=	0·015" = 0·038		
Minimum reluctance	=	0·008		
Maximum -	=	0·012		
Mean -	=	0·01		
Field winding	=	70 turns of # 15 B.W.G. 0·072" d.c.c. & 0·085". in 2 spools of 35 turns each 7×5.		
Mean turn	=	0·6'		
Total length of wire	=	42'		
- resistance	=	0·084 ω. @ 20° C.		
- weight	=	0·66 lbs. = 11 oz. nearly.		
Armature winding	=	50 turns of # 20 B.W.G. or 19 B.S. 0·035" d.c.c. & 0·038" on each limb. = 5 mean layers of 10 turns each.		
Length of mean turn	=	3·8" = 0·25'		
Total length of wire	=	12·5' × 3 = 37·5'		
- resistance	=	0·316 ω		
Mean Resistance between brushes	=	0·070 ω. @ 20° C		0·075 ω.
Total weight of wire	=	0·14 lbs. = 2¼ oz.		
Cross section of one limb	=	(0·453 + 0·76 × 1·65) = 1·707 sq: cms:		0·775×3·14 = 1·970 sms: in circle
MMF at 2 amps:	=	88 × 2 = 176		
Mean flux	=	17,600		
- intensity in arm	=	10,310		
- - in field	=			
at constricted point	=	3,120 (without leakage)		
Mean EMF of armature	=	¼ eq flux = ¼ × 17,600 × 150 × 35 = 1·232 volt. @ 35 rps.		
Total res: of motor	=	0·15 ω @ 20° C.		
Drop in motor	=	0·3 volt.		
Res: of motor	=	0·158 ω @ 20° C.		
Diam of shaft in bearings	=	0·155" = 0·394		
Mass of arm	=	22 gs.		
Diam: of brush pressure	=	1·750		

Design for a new motor meter for the Edison Patent Syndicate.

30th Sept.

A continuous current, shunt wound, Edison drums motor, with the armature vertical and running upon a jewel bearing.

Length of armature body = 5.08 . 2"

Diam. ext. . . . = 5.08 2" Bore = 6.28" × π = 5¾" available.

" int. . . . = 3.49 1.375"

Cross section . . . = 4.04 sq. ins. on each side = 8.09 in all. × 0.90 = 6.46 available.

Polar bore diameter = 5.71 2.25" circ. = 17.94

Polar angles = 136°

" surfaces = 34.4 sq. ins.

Entrefer = 0.215 cms.

Total air reluctance = $\frac{0.63}{34.4} \times 2 = 0.0183$.

Winding = 2 layers each of 120 turns + 20 extra 0.035" d.s.c. & 0.039" Twenty skins of 6 turns in each. Twenty fibre strips of 0.020".

Total wire all round = 240

Length of one turn = 0.9'

Total length of wire = 180'

Total Weight . . = 0.668 lb.

" resistance . " = 1.52Ω ÷ ⅝ = 0.19Ω effective @ 20°C. Measured 0.191Ω = 29.4Ω.

Commutator bars = 20

Diameter of commutator = 1.0 ins = 0.47

Field winding = # 11 Brs. 0.0907". s.c.c. & 0.099". 7 layer of 310 turns = 2170 turns

Mean diameter = 1.105" circ. = 5.67" = 0.472'

Total length = 1450 3' on each afore = 2174.6' in all

" weight. = 2.6 lbs.

" resist ance = 0.282Ω @ 20°C. 0.323 = @ 60°C.

MMF. per amp. = 600

Reluctance = 0.02

Flux per amp. = 30,000.

Exciting Current in field at start = $\frac{22}{46}$ = 0.43

" " armature " = 0.57

With one amp. thro meter.

Flux with no residual mag = 12,900.

Torque at start. = $\frac{12,900 \times 0.027 \times 240}{6,265}$ = 28.6 cm-gms.

Cross section of field core = 6.7 sq. cms.

Flux at 18,000 C.G.S. = 120,600 produced at 4 amp.

Leakage factor = 1.35

Flux in armature = 89,350.

Density " " = 13,820.

EMF of armature at full flux = 90,000 × 240 = 216 × 10⁷ = 0.216 volt per rev. per sec.

At 2 Volts generate EMF = 600 r.p.m.

1.05 " " = 500 " "

Thickness of armature

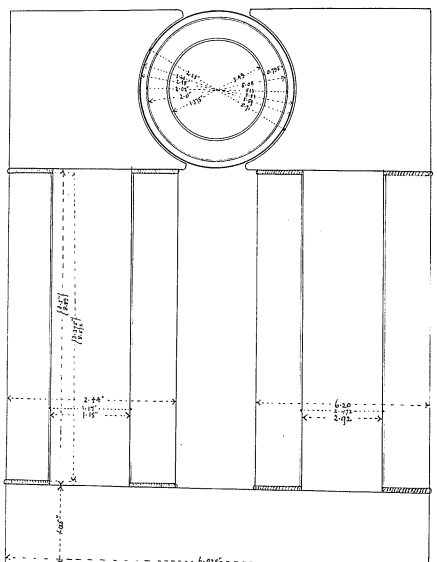
" (mica) insulation = 0.010"

" of bindering = 0.010"

Clearance = 0.0250".

Weight of armature = 700 gms.

Full sized plan of motor in section through core centres. Depth of pole faces 2"



Area of unsaturated core 6.938
" " full magnet 10.190
Total contents of winding 1890.8 cc.

$d = 2.016 \sqrt{\text{form} + \text{wires}/\frac{\text{area}}{\text{pitch}}}$

1870

+ 0.2560 cms

0.2560

2.0130

2 = 2.266 cms = 0.892" = 0.907 s.c.c. 0.935"

Armature 11 sq. # 26 B.W.G. 0.035" d.s.c. & 0.039"

Field 5 lbs. 9 q # 11 Brs 0.0907" s.c.c. & 0.099"

On the Calculated Carrying Capacity of various

No.	Conductor	Cross Circular mils	Section Sq: cms.	Resistance per cm. @ 0°C.	@ 55°C	Radii of first insulation	Thermal resistance ($\log_e \frac{r_2}{r_1}$)	Radii of second covering	Thermal resistance ($\log_e \frac{r_3}{r_2}$)	Radii of third coating	Thermal resistance $\log_e \frac{r_4}{r_3}$	Total thermal resistance $\frac{\rho}{2\pi}(\log_e \frac{r}{r})$	Diam: of exterior covering	Surf[ace] per …
			50.71	1.627×10^{-6}	1.2279 / 1.9996×10^{-6}					1.131 1.400		ρ = 750; 274.9; 119.4		
1	19 # 10 B.S. 0.103	197,300	0.9996	1.628×10^{-6}	1.999×10^{-6}	0.615/0.685 = 1.439	0.3640	1.06/1.24 = 1.17	0.1570	1.45/1.64 + 2.21/1.43	0.218	88.22	4.86	15.27
2	18 # 11 B.W.G. 0.120	259,200	1.3132	1.239	1.521 .	1.005/0.760 = 1.322	0.2790	1.34/1.165 = 1.150	0.1398	1.805/1.55 + 2.55/2.4	0.2250	76.87	5.16	16.2[…]
3	36 # 10 B.S. 0.103	373,810	1.8940	8.590×10^{-7}	1.055 .	2.38/1.81 = 1.315	0.2738	2.17/1.79 = 1.136	0.1265	3.45/3.60 + 5.65/3.38	0.1455	65.16	5.65	17.75
4	36 # 12 B.W.G. 0.109	427,720	2.1672	7.506 -	9.216×10^{-7}	2.39/1.90 = 1.258	0.09968	3.22/2.80 = 1.150	0.06070	4.22/3.71 + 5.45/5.50	0.08836	67.82	5.95	18.69
5	36 # 9 B.S. 0.114	471,200	2.387	6.816 -	8.368 -	2.47/2.01 = 1.229	0.08955	3.29/2.90 = 1.1345	0.05480	4.31/3.72 + 6.12/5.71	0.08404	62.79	6.12	19.33
6	36 # 8 B.S. 0.1285	594,500	3.012	5.401 -	6.63 -	2.73/2.29 = 1.197	0.07809	3.60/3.21 = 1.121	0.04961	4.50/4.08 + 6.35/5.90	0.07439	55.55	6.35	19.95
7	7 # 11 B.S. 0.0907	57,582	0.2918	5.576×10^{-6}	6.846×10^{-6}	1.15/0.65 = 1.77	0.24797	1.82/1.50 = 1.213	0.08386	2.53/2.29 + 3.97/3.56	0.05866	115.6	3.97	12.47
8	7 # 12 B.W.G. 0.109	83,167	0.4215	3.860 -	4.738 "	1.28/0.78 = 1.641	0.21511	1.99/1.76 = 1.131	0.05346	2.68/2.40 + 4.20/3.80	0.09141	98.96	4.20	13.2[…]
9	7 # 8 B.S. 0.1285	115,584	0.5856	2.778 -	3.411 -	1.40/0.92 = 1.521	0.18213	2.00/1.70 = 1.176	0.07041	2.90/2.50 + 4.28/4.0	0.09384	95.22	4.28	13.4[…]
10	19 # 14 B.W.G. 0.083	130,891	0.6632	2.453 -	3.012 -	1.49/1.03 = 1.446	0.16017	2.28/1.88 = 1.213	0.08356	3.12/2.75 + 4.52/4.2	0.08681	90.95	4.52	14.2[…]
11	19 # 11 B.S. 0.0907	156,294	0.7920	2.054 -	2.522 -	1.63/1.12 = 1.456	0.16316	2.48/2.01 = 1.234	0.09132	3.30/2.92 + 4.80/4.38	0.09289	95.50	4.80	15.09
12	19 # 13 B.W.G. 0.095	171,475	0.8688	1.8725 -	2.299 -	1.63/1.19 = 1.370	0.13672	3.40/3.01 = 1.130	0.05308	3.15/2.85 + 4.6/4.1	0.09335	77.84	4.60	14.4[…]
13	36 # 10 B.S. 0.103	373,810	1.8940	8.590×10^{-7}	1.055×10^{-6}	2.33/1.77 = 1.316	0.11926	3.14/2.76 = 1.138	0.05614	3.95/3.58 = 1.104	0.04297	60.04	3.95	12.4[…]
14	36 # 12 B.W.G. 0.109	427,720	2.1672	7.506 -	9.216×10^{-7}	2.38/1.86 = 1.280	0.10721	3.17/2.77 = 1.144	0.05843	3.97/3.58 = 1.109	0.04493	57.89	3.97	12.4[…]
15	36 # 9 B.S. 0.114	471,200	2.387	6.816 -	8.368 .	2.51/1.98 = 1.268	0.10311	3.22/2.90 = 1.11	0.04532	4.05/3.71 = 1.092	0.03822	51.31	4.05	12.7[…]
16	36 # 8 B.S. 0.1285	594,500	3.012	5.401 .	6.63 .	2.70/2.21 = 1.222	0.08707	3.68/3.20 = 1.150	0.06070	4.50/4.11 = 1.096	0.03981	51.57	4.50	14.11
17	36 # 7 B.S. 0.1443	749,800	3.799	4.282 -	5.257 .	3.12/2.58 = 1.209	0.08243	3.91/3.55 = 1.101	0.04179	4.57/4.31 = 1.061	0.02572	41.21	4.57	14.35
18	36 # 6 B.S. 0.162	968,200	4.906	3.316 -	4.072 -	3.55/2.89 = 1.228	0.08920	4.4/3.95 = 1.114	0.04689	5.56/5.20 = 1.069	0.02898	45.37	5.20	16.3[…]
19	7 # 8 B.S. 0.1285	115,584	0.5856	2.778×10^{-6}	3.411×10^{-6}	1.48/0.90 = 1.644	0.21590	2.23/1.85 = 1.205	0.05079	2.95/2.69 = 1.108	0.04454	93.86	2.98	9.36
20	19 # 14 B.W.G. 0.083	130,891	0.6632	2.453 .	3.012 .	1.50/1.05 = 1.429	0.15503	2.28/1.92 = 1.188	0.07482	3.07/2.71 = 1.133	0.05423	78.10	3.07	9.65
21	19 # 11 B.S. 0.0907	156,294	0.7920	2.054 .	2.522 .	1.67/1.15 = 1.452	0.16197	2.52/2.10 = 1.200	0.07918	3.21/2.97 = 1.081	0.03383	75.6	3.21	10.69
22	19 # 13 B.W.G. 0.095	171,475	0.8688	1.8725 -	2.299 -	1.63/1.19 = 1.456	0.16316	2.40/2.00 = 1.200	0.07918	3.13/2.82 = 1.110	0.04532	79.08	3.13	9.84
23	19 # 10 B.S. 0.103	197,300	0.9996	1.628 "	1.999 -	1.75/1.34 = 1.306	0.10894	2.50/2.10 = 1.191	0.07591	3.21/2.91 = 1.103	0.04258	64.45	3.21	10.09
24	18 # 11 B.W.G. 0.120	259,200	1.3132	1.239 -	1.521 -	2.01/1.50 = 1.340	0.12710	2.71/2.34 = 1.158	0.04759	3.50/3.15 = 1.111	0.04571	60.60	3.50	11.0[…]
25	1 # 6 B.S. 0.162	26,244	0.1330	1.2235×10^{-5}	1.502×10^{-5}	0.81/0.42 = 1.929	0.28533	1.39/1.10 = 1.264	0.10175	2.10/1.87 = 1.123	0.05038	120.30	2.10	6.6[…]
26	1 # 4 B.S. 0.2043	41,738	0.2115	7.692×10^{-6}	9.444×10^{-6}	0.89/0.52 = 1.711	0.23325	1.52/1.28 = 1.187	0.07445	2.30/2.02 = 1.139	0.05652	100.1	2.30	7.2[…]
27	7 # 11 B.S. 0.0907	57,582	0.2918	5.576 -	6.846 -	1.12/0.60 = 1.867	0.27114	1.82/1.49 = 1.221	0.08672	2.70/2.31 = 1.169	0.06781	117.0	2.70	8.4[…]
28	7 # 9 B.S. 0.1144	91,609	0.4642	3.505 -	4.302 -	1.23/0.81 = 1.519	0.18156	1.98/1.62 = 1.222	0.08707	2.71/2.38 = 1.139	0.05652	89.4	2.71	8.[…]
29	7 # 11 B.S. 0.0907	57,582	0.2918	5.576 -	6.846 -	1.13/0.66 = 1.567	0.27114	1.80/1.5 = 1.200	0.07918	2.45/2.20 = 1.114	0.04689	109.2	2.45	7.[…]
30	7 # 8 B.S. 0.1285	115,584	0.5856	2.778 -	3.411 .	1.42/0.98 = 1.449	0.16107	2.10/1.77 = 1.186	0.07408	2.81/2.52 = 1.115	0.04727	77.6	2.81	8.[…]
31	1 # 16 B.S. 0.0508	2,581	0.01308	1.244×10^{-4}	1.527×10^{-4}	0.52/0.16 = 3.250	0.51188	1.26/0.81 = 1.556	0.19201			193.5	1.26	3.9[…]
32	1 # 16 B.S. 0.0508	2,581	0.01308	1.244 "	1.527 -	0.50/0.12 = 4.166	0.61972	1.10/0.82 = 1.341	0.12743	1.60/1.35 = 1.185	0.07372	225.7	1.60	5.0[…]
33	1 # 14 B.S. 0.0641	4,109	0.02077	7.834×10^{-5}	9.617×10^{-5}	0.50/0.18 = 2.778	0.44373	1.20/0.88 = 1.364	0.13481	1.73/1.42 = 1.218	0.08565	182.6	1.73	5.4[…]
34	1 # 12 B.S. 0.0808	6,529	0.03308	4.918 -	6.037 .	0.58/0.21 = 2.762	0.44122	1.15/0.90 = 1.278	0.10653	1.70/1.42 = 1.197	0.07809	172.0	1.70	5.3[…]
35	1 # 10 B.S. 0.1019	10,384	0.05261	3.092 .	3.796 .	0.60/0.28 = 2.143	0.33102	1.20/0.97 = 1.237	0.09237	1.92/1.63 = 1.178	0.07115	135.9	1.92	6.0[…]
36	1 # 8 B.S. 0.1285	16,512	0.08367	1.945 -	2.387 .	0.70/0.32 = 2.187	0.33985	1.30/1.08 = 1.204	0.08063	1.94/1.71 = 1.134	0.05461	130.6	1.94	6.1[…]
37	1 # 14 B.S. 0.0641	4,109	0.02077	7.834 -	9.617 -	0.50/0.21 = 2.381	0.37676	1.38/0.82 = 1.683	0.22608		.6028 "	165.7	1.38	4.3[…]
38	1 # 12 B.S. 0.0808	6,529	0.03308	4.918 .	6.037 .	0.57/0.25 = 2.280	0.35793	1.39/0.89 = 1.562	0.19368		.55161	151.7	1.39	4.3[…]
39	1 # 10 B.S. 0.1019	10,384	0.052261	3.092 .	3.796 .	0.68/0.29 = 2.345	0.37014	1.50/0.95 = 1.579	0.19838		.56852	156.3	1.50	4.[…]
40	1 # 8 B.S. 0.1285	16,512	0.08367	1.945 .	2.387 .	0.75/0.35 = 2.143	0.33102	1.52/1.02 = 1.490	0.17319		.50421	138.6	1.52	4[…]
41	1 # 6 B.S. 0.162	26,244	0.1330	1.2235 .	1.502 .	0.80/0.42 = 1.905	0.27990	1.65/1.12 = 1.473	0.16820		.44810	123.2	1.65	5[…]
42	1 # 4 B.S. 0.2043	41,738	0.2115	7.692×10^{-6}	9.444×10^{-6}	0.91/0.52 = 1.750	0.24304	1.80/1.22 = 1.476	0.16909		.41213	113.3	1.80	5[…]
43	18 # 11 B.W.G. 0.120	259,200	1.3132	1.239×10^{-6}	1.521×10^{-6}	2.00/1.56 = 1.282	0.10789	2.86/2.30 = 1.243	0.09447		.20236	55.6	2.86	9[…]
44	36 # 10 B.S. 0.103	373,810	1.8940	8.590×10^{-7}	1.055 -	2.37/1.82 = 1.302	0.11461	3.32/2.78 = 1.194	0.07700		.19161	52.68	2.78	
45	36 # 12 B.W.G. 0.109	427,720	2.1672	7.506 -	9.216×10^{-7}	2.34/1.87 = 1.251	0.09726	3.22/2.77 = 1.162	0.06521		.16247	44.66	2.77	
46	36 # 9 B.S. 0.114	471,200	2.387	6.816 -	8.378 .	2.50/2.0 = 1.25	0.09691	3.40/2.80 = 1.214	0.08422		.18113	49.80	3.40	
47	36 # 7 B.S. 0.1443	749,800	3.799	4.282 -	5.257 .	3.04/2.65 = 1.162	0.06521	4.11/3.52 = 1.168	0.06744		.13265	36.47	4.11	
48	36 # 6 B.S. 0.162	968,200	4.906	3.316 .	4.072 -	3.55/2.89 = 1.228	0.08920	4.4/3.95 = 1.114	0.04689		.13609	37.42	4.40	

List of Samples of Siemens Cables

Manufactured by the Edison General Electric Company.

Explanation of Signs: C - Cable; L - Lead; A - Asphalt; I - Iron Armoring; W - Wire Armoring; BL - Bare Lead Cable; LA - Asphalted Lead Cable; LAI - Iron Armored Lead Cable; LAW - Wire-Armored Lead Cable; LAIW - Iron and Wire Armored (Submarine) Cable; CM - Sectional Area of Conductor in Circular Mils.

Telegraph Cables Submarine.

78 C.L.A. 18 B.W.G.	79 C.L.A. 18 B.W.G.
80 C.L.A. 7/18 B.W.G.	81 C.L.A.W. 7/18 B.W.G.
82 C.L.A. 7/16 B.W.G.	83 C.L.A.W. 7/16 B.W.G.
84 C.L.A. 7/14 B.W.G.	85 C.L.A.W. 7/14 B.W.G.
86 C.L.A. 7/12 B.W.G.	87 C.L.A.W. 7/12 B.W.G.
88 C.L.A. 7/10 B.W.G.	89 C.L.A.W. 7/10 B.W.G.
90 C.L.A. 7/16 B.W.G.	91 C.L.A.W. 7/16 B.W.G.
92 C.L.A. 7/14 B.W.G.	93 C.L.A.W. 7/14 B.W.G.
94 C.L.A.W. 7/12 B.B.S.	95 C.L.A. 7/12 B.B.S.
96 C.L.A.W. 7/12 B.B.S.	97 C.L.A. 7/12 B.B.S.
98 C.L.A.W. 7/12 B.B.S.	99 C.L.A. 9/12 B.B.S.
100 C.L.A.W. 7/12 B.B.S.	101 C.L.A. 9/12 B.B.S.
102 C.L.A.W. 7/12 B.B.S.	103 C.L.A. 9/12 B.B.S.
104 C.L.A.W. 7/12 B.B.S.	105 C.L.A. 9/12 B.B.S.
106 C.L.A.W. 7/12 B.B.S.	107 C.L.A. 9/12 B.B.S.
108 C.L.A.W. 7/12 B.B.S.	109 C.L.A. 9/12 B.B.S.

Light and Power Cables.

Tested for 2000 Volts Continuous Current.

1 CLAIW. 300000 CM.	2 CLAIW. 250000 CM.	3 CLAIW. 350000 CM.	4 CLAIW. 400000 CM.	5 CLAIW. 500000 CM.	6 CLAIW. 600000 CM.
7 CLAIW. 80000 CM.	8 CLAIW. 60000 CM.	9 CLAIW. 100000 CM.	10 CLAIW. 150000 CM.	11 CLAIW. 120000 CM.	12 CLAIW. 180000 CM.
13 CLAI. 350000 CM.	14 CLAI. 400000 CM.	15 CLAI. 500000 CM.	16 CLAI. 600000 CM.	17 CLAI. 800000 CM.	18 CLAI. 1000000 CM.
19 CLAI. 1000000 CM.	20 CLAI. 1200000 CM.	21 CLAI. 1500000 CM.	22 CLAI. 1800000 CM.	23 CLAI. 2000000 CM.	24 CLAI. 2500000 CM.
25 CLAW. 7 6 0 0 B	26 CLAW. 7 4 B S	27 CLAI. 60000 CM.	28 CLAI. 80000 CM.	29 CLAI. 90000 CM.	30 CLAI. 100000 CM.
31 CLA. 7/8 B S	32 CLAW. 7/8 B.S.	33 CLAW. 7/4 B S	34 CLAW. 7/8 B S	35 CLAW. 7/10 B S	36 CLAW. 7/12 B S
37 C.L.A. 7/14 B S	38 C.L.A. 7/12 B.S.	39 C.L.A. 7/10 B S	40 C.L.A. 7/8 B S	41 C.L.A. 7/8 B S	42 C.L.A. 7/6 B S
43 C.L.A. 250000 CM.	44 C.L.A. 350000 CM.	45 C.L.A. 400000 CM.	46 C.L.A. 500000 CM.	47 C.L.A. 600000 CM.	48 C.L.A. 1000000 CM.
49 C.L.A. 80000 CM.	50 C.L.A. 120000 CM.	51 C.L.A. 100000 CM.	52 C.L.A. 150000 CM.	53 C.L.A. 180000 CM.	54 C.L.A. 250000 CM.
55 C.L. 200000 CM.	56 C.L. 350000 CM.	57 C.L. 400000 CM.	58 C.L. 500000 CM.	59 C.L. 600000 CM.	60 C.L. 1000000 CM.
61 C.L. 50000 CM.	62 C.L. 100000 CM.	63 C.L. 120000 CM.	64 C.L. 150000 CM.	65 C.L. 190000 CM.	66 C.L. 250000 CM.
67 C.L. 7/8 B S	68 C.L. 7/6 B S	69 C.L. 7/4 B S	70 C.L. 60000 CM.	71 C.L. 90000 CM.	72 C.L. 80000 CM.
		73 C.L. 7/10 B S	74 C.L. 7/14 B S	75 C.L. 7/12 B S	76 C.L. 7/10 B S

Telegraph Cables Underground.

110 C.L. 7/18 B S	111 C.L. 7/16 B S
112 C.L.A. 7/18 B S	113 C.L.A. 7/16 B S
114 C.L.A.W. 7/18 B S	115 C.L.A.W. 7/16 B S

77 C.L.A.I. 3-Conductor Cable. 1-400000 CM. 1-1-120000 CM.

Telephone Cables.

116 C.L.A.I. 50 Pairs 7/18 B S	117 C.L.A. 50 Pairs 7/18 B S	118 C.L. 50 Pairs 7/18 B S

Examples of Siemens Cable for electric light distribution.

Diam: Conductor Inches	Sectional area in m/m	Diam: Insulation Inches	Sectional area in m/m	Number of Wires in Strand	Diam: of Wires in Inches	Sectional area of Conductor in m/m	Sectional area of Insulation in m/m	Sectional area of Lead in m/m	Resistance per knot in Ohms	Resistance per knot in Ohms	Weight per knot in lbs.	Weight per knot in lbs.	Weight per knot in lbs.	Weight per knot in lbs.
0.2834	141.910	376.5	12.5	0.1147	79.905	266.3	0.00115	0.00115	9.5	85	0.1727	97.900	296.5	
0.2552	213.930	462.4	12.5	0.1626	126.915	327.	-	0.01799	0.01974	10	15	0.1951	128.300	358.2	
0.3316	362.700	603.0	12.5	0.1918	181.930	426.4	-	0.0197	0.021145	10.5	16.5	0.2225	234.700	484.8	
0.3687	444.600	632.5	12.5	0.20134	208.000	449.3	-	0.020714	0.02149	10.6	15	0.2212	240.000	489.9	
0.3982	498.800	690.0	12.5	0.1997	237.900	497.8	-	0.02138	0.02310	10.8	16.8	0.2357	281.600	530.7	
0.4500	635.400	821.9	12.5	0.2250	337.700	581.1	-	0.02214	0.02389	10.8	16.8	0.2366	286.900	622.0	
0.163	31.870	177.7	12.5	0.1082	15.795	125.7	-	0.01824	0.01859	8.9	16.1	0.1390	20.350	112.7	
0.226	53.320	230.9	12.5	0.1263	26.660	163.3	-	0.01863	0.01940	9.1	15.5	0.1566	33.060	181.9	
0.255	76.480	277.4	12.5	0.1312	38.240	196.2	-	0.01942	0.02067	9.7	15.8	0.1607	47.100	217.1	
0.298	91.250	302.1	12.5	0.1374	45.623	213.6	-	0.01976	0.02051	9.6	15.4	0.1693	56.200	237.1	
0.318	103.800	322.2	12.5	0.1397	51.900	227.8	-	0.01994	0.02084	9.8	16.0	0.1675	66.420	257.7	
0.372	139.700	373.8	12.5	0.1681	69.850	264.3	-	0.01981	0.02079	10.8	16.5	0.1863	81.650	286.7	
0.405	329.100	628.3	12.5	0.2813	197.400	444.3	-	0.01977	0.01852	12.9	11.1	0.2218	191.000	437.1	
0.318	468.600	684.6	12.5	0.2857	234.300	484.0	-	0.01985	0.01860	13.1	11.9	0.2256	273.900	523.3	
0.573	582.300	763.1	12.5	0.2637	291.150	539.6	-	0.01912	0.01987	12.9	11.2	0.2183	266.900	516.9	
0.614	731.200	855.1	12.5	0.2743	366.600	605.5	-	0.01969	0.01744	13.2	11.8	0.2288	346.100	587.5	
0.667	1153.200	1074.0	12.5	0.3034	577.000	759.6	-	0.01620	0.01779	13.4	10.6	0.2572	489.200	699.4	
0.711	1583.000	1163.	12.5	0.2756	1.676.500	822.5	-	0.01813	0.01989	13.1	11.9	0.2622	644.100	802.6	
0.264	74.100	279.5	12.5	0.1332	37.050	197.6	-	0.01869	0.01821	11.7	11.3	0.1817	141.300	283.8	
0.202	116.300	324.1	12.5	0.1601	53.150	230.6	-	0.01971	0.01834	12.7	10.3	0.1975	52.290	228.7	
0.307	131.200	362.2	12.5	0.1624	65.600	256.1	-	0.01120	0.01295	12.6	12.4	0.1640	65.040	255.0	
0.361	137.500	370.9	12.5	0.1581	64.750	262.2	-	0.01092	0.01267	13.5	12.5	0.1581	64.750	262.2	
0.880	1.914.100	1440.6	12.5	0.1940	957.050	311.5	-	0.0120	0.0245	13.6	11.4	0.1764	957.450	297.5	
0.426	271.300	520.9	12.5	0.2263	135.650	369.5	-	0.0122	0.01396	13.5	11.5	0.1898	134.700	358.1	
0.078	13.840	117.6	12.5	0.1039	6.920	83.2	-	0.00721	0.01987	12.0	13.8	0.1081	71.940	94.8	
0.498	24.450	162.6	12.5	0.1249	13.225	115.0	-	0.00802	0.00977	12.6	12.4	0.1229	131.208	116.5	
0.237	31.210	176.7	12.5	0.1069	15.605	124.9	-	0.00941	0.01116	11.9	14.1	0.1208	166.000	121.7	
0.297	65.010	255.0	12.5	0.1398	32.505	180.3	-	0.00945	0.01120	13.5	12.5	0.1398	32.505	180.3	
0.290	83.450	182.9	12.5	0.1146	16.720	129.3	-	0.00855	0.01103	11.8	13.2	0.1289	17.600	132.9	
0.322	94.100	307.3	12.5	0.1611	47.220	217.2	-	0.00780	0.01158	12.2	11.8	0.1421	22.960	151.0	
0.172	8.465	29.1	12.5	0.0646	4.233	20.6	-	0.00548	0.00615	11.4	13.6	0.0703	4.603	21.5	
0.108	7.255	26.9	12.5	0.0554	3.628	19.1	-	0.00559	0.00733	9.4	15.6	0.0691	4.552	21.3	
0.169	14.241	37.7	12.5	0.0685	7.12.	26.7	-	0.00604	0.00779	10.3	14.7	0.0805	7.028	32.1	
0.153	21.107	46.1	12.5	0.0727	10.54.	34.7	-	0.00892	0.00967	10.3	14.2	0.0824	7.368	37.0	
0.184	41.847	69.6	12.5	0.0920	20.94.	49.2	-	0.00869	0.00946	11.6	13.4	0.0986	2.597	57.0	
0.214	80.76	89.5	12.5	0.0957	40.08	63.3	-	0.00677	0.00832	11.4	13.1	0.1003	43.202	64.8	
0.289	156.9	39.6	12.5	0.0785	78.5	28.0	-	0.00682	0.00857	12.0	13.0	0.0781	81.58	28.5	
0.1628	27.30	52.2	12.5	0.0824	13.65	36.9	-	0.00685	0.00660	12.5	12.5	0.0824	13.65	36.9	
0.1579	42.12.	64.9	12.5	0.0890	21.06	45.9	-	0.00823	0.00898	12.0	13.0	0.08316	21.98	46.8	
0.1804	76.56	86.9	12.5	0.0982	38.28	61.5	-	0.00820	0.00908	12.6	12.4	0.08946	37.48	61.2	
0.2030	132.20	116.3	12.5	0.1015	66.10	82.2	-	0.00875	0.00980	13.0	12.0	0.09712	64.88	80.5	
0.2209	203.70	152.9	12.5	0.1104	101.85	103.1	-	0.00627	0.00802	13.1	11.9	0.10500	111.20	105.5	
0.344	295.600	543.7	12.5	0.2248	147.800	378.4	-	0.00999	0.01174	15.1	11.9	0.1780	177.060	342.1	
0.4145	449.800	670.7	12.5	0.2373	224.900	471.2	-	0.00969	0.01144	15.6	9.4	0.1784	169.100	411.3	
0.5599	745.800	863.6	12.5	0.2800	373.900	610.7	-	0.00966	0.01141	16.5	9.5	0.1903	286.500	534.4	
0.5020	509.100	714.0	12.5	0.2510	254.550	504.3	-	0.01195	0.01260	15.4	9.6	0.1928	230.200	479.8	
0.6856	130.4000	1142.0	12.5	0.3428	652.000	807.4	-	0.01433	0.01689	15.8	9.2	0.2523	480.000	692.8	
0.6680	1.604.000	1281.0	12.5	0.3340	802.000	895.8	-	0.01534	0.01703	15.2	9.8	0.2620	642.700	802.3	

Calculated Carrying Capacities of Samples of Hemine 1914

No.	Conductor	Cross Section mils	Section Sq. cms	Res. per cm. @ 0°C	Res. per cm. @ 55°C	Diameter of Wire Thou.	Diameter of Wire Cm.	Diameter of Wire Thou.	Diameter of Wire Cm.	Diameter of Finished Cable Thou.	Diameter of Finished Cable Cm.	Total Thermal Res.	Diam. of Finished Cable Thou.	Conductor per cm.	Insulation per cm.	Total Emissivity	W	θ₁	W₁	C₁	C₂	Remarks
49	Tinned Copper	85.167	0.04315	3.060 ×10⁻⁶	4.738 ×10⁻⁶	1/64 = 0.0156	0.03969	1/64 = 0.0156	0.03969	0.0253	0.06426	73.84	1.99	6.23			0.3386	73800	271.7	12.5°	0.1693	36.900	192.1	0.00175	0.006924	0.00969	102	9.8	0.1328	24.920	167.4
50	Tinned Copper	130.561	0.06632	2.653 ,,	4.108 ,,	0.0196	0.04978	3/64 = 0.0470	0.10581		0.12327	72.36	2.32	7.29			0.3455	111.700	338.7	"	0.1727	37.350	239.6	"	0.005670	0.008926	116	10.4	0.1437	47.700	218.4
51	Tinned Copper	195.831	0.09946	1.769 ,,	2.739 ,,	0.0236	0.05994	4/64 = 0.0625	0.15875		0.17993	85.89	2.83	7.91			0.3611	154.700	393.3	"	0.1950	77.350	278.1	"	0.005851	0.010036	125	9.9	0.1569	61.260	249.7
52	Tinned Copper	256.640	0.13035	1.350 ,,	2.091 ,,	0.0276	0.07010	5/64 = 0.0781	0.19837		0.22116	94.11	3.32	7.67			0.3801	198.800	422.9	"	0.2058	89.400	299.0	"	0.006015	0.010940	133	9.7	0.1695	74.820	273.5
53	Tinned Copper	321.440	0.16331	1.077 ,,	1.668 ,,	0.0309	0.07849	6/64 = 0.0938	0.23812		0.26126	103.6	3.72	8.14			0.4110	248.800	452.9	"	0.2185	107.800	324.8	"	0.006103	0.011078	140	9.7	0.1821	87.360	296.1
54	Tinned Copper	397.320	0.20188	0.8708 ,,	1.353 ,,	0.0345	0.08763	7/64 = 0.1094	0.27781		0.29848	112.9	4.12	8.56			0.4218	311.900	459.2	"	0.2249	135.000	344.8	"	0.006193	0.011187	146	9.7	0.1937	97.860	286.1
55	Tinned Copper	487.200	0.24763	0.7102 ,,	1.103 ,,	0.0384	0.09754	8/64 = 0.1250	0.31750		0.33818	121.6	4.52	8.96			0.4322	381.400	466.5	"	0.2304	165.000	352.8	"	0.006273	0.011287	152	9.7	0.2045	107.400	274.6
56	Tinned Copper	597.600	0.30376	0.5791 ,,	0.8995 ,,	0.0427	0.10846	9/64 = 0.1406	0.35719		0.37787	130.4	4.92	9.36			0.4422	467.600	469.8	"	0.2356	202.400	358.2	"	0.006347	0.011381	158	9.7	0.2150	117.600	262.6
57	Tinned Copper	732.600	0.37234	0.4726 ,,	0.7340 ,,	0.0475	0.12065	10/64 = 0.1562	0.39688		0.41756	139.2	5.32	9.76			0.4519	573.400	472.4	"	0.2405	248.400	363.2	"	0.006417	0.011470	164	9.7	0.2252	128.400	258.0
58	Tinned Copper	898.200	0.45662	0.3853 ,,	0.5984 ,,	0.0528	0.13411	11/64 = 0.1719	0.43656		0.45724	148.0	5.72	10.16			0.4611	703.400	474.9	"	0.2453	304.800	367.4	"	0.006483	0.011554	170	9.7	0.2352	139.200	254.2
59	Tinned Copper	1102.000	0.56031	0.3140 ,,	0.4876 ,,	0.0587	0.14910	12/64 = 0.1875	0.47625		0.49693	156.8	6.12	10.56			0.4701	863.400	477.2	"	0.2501	374.000	371.2	"	0.006545	0.011634	176	9.7	0.2451	150.000	250.0
60	Tinned Copper	1352.000	0.68750	0.2559 ,,	0.3974 ,,	0.0653	0.16586	13/64 = 0.2031	0.51594		0.53662	165.4	6.52	10.96			0.4790	1059.000	479.5	"	0.2548	459.000	375.2	"	0.006604	0.011710	182	9.7	0.2550	161.400	246.6
61	Tinned Copper	1659.000	0.84375	0.2085 ,,	0.3238 ,,	0.0726	0.18440	14/64 = 0.2188	0.55563		0.57631	174.2	6.92	11.36			0.4878	1299.000	481.9	"	0.2595	563.000	379.2	"	0.006661	0.011784	188	9.7	0.2649	172.800	243.2
62	Tinned Copper	2035.000	1.03500	0.1700 ,,	0.2639 ,,	0.0807	0.20497	15/64 = 0.2344	0.59531		0.61599	183.0	7.32	11.76			0.4966	1594.000	484.3	"	0.2643	691.000	383.2	"	0.006716	0.011856	194	9.7	0.2748	184.200	239.8
63	Tinned Copper	2497.000	1.27000	0.1385 ,,	0.2150 ,,	0.0897	0.22784	16/64 = 0.2500	0.63500		0.65568	191.8	7.72	12.16			0.5054	1956.000	486.8	"	0.2691	848.000	387.2	"	0.006770	0.011926	200	9.7	0.2847	195.600	236.4
64	Tinned Copper	3065.000	1.55875	0.1129 ,,	0.1752 ,,	0.0996	0.25298	17/64 = 0.2656	0.67469		0.69537	200.6	8.12	12.56			0.5142	2401.000	489.2	"	0.2739	1041.000	391.2	"	0.006822	0.011994	206	9.7	0.2946	206.400	233.2
65	Tinned Copper	3762.000	1.91375	0.0919 ,,	0.1427 ,,	0.1106	0.28092	18/64 = 0.2812	0.71438		0.73506	209.4	8.52	12.96			0.5230	2947.000	491.6	"	0.2787	1278.000	395.2	"	0.006873	0.012060	212	9.7	0.3045	217.200	230.0
66	Tinned Copper	4618.000	2.34875	0.0749 ,,	0.1162 ,,	0.1228	0.31191	19/64 = 0.2969	0.75406		0.77474	218.2	8.92	13.36			0.5318	3617.000	494.0	"	0.2835	1569.000	399.2	"	0.006923	0.012124	218	9.7	0.3144	228.000	227.2
67	Tinned Copper	5668.000	2.88375	0.0610 ,,	0.0947 ,,	0.1363	0.34620	20/64 = 0.3125	0.79375		0.81443	227.0	9.32	13.76			0.5406	4440.000	496.4	"	0.2883	1926.000	403.2	"	0.006972	0.012187	224	9.7	0.3243	238.800	217.4
68	Tinned Copper	6958.000	3.53875	0.0497 ,,	0.0771 ,,	0.1513	0.38430	21/64 = 0.3281	0.83344		0.85412	235.8	9.72	14.16			0.5494	5450.000	498.8	"	0.2931	2364.000	407.2	"	0.007020	0.012249	230	9.7	0.3342	249.600	208.0
69	Tinned Copper	8541.000	4.34375	0.0405 ,,	0.0628 ,,	0.1679	0.42647	22/64 = 0.3438	0.87313		0.89381	244.6	10.12	14.56			0.5582	6690.000	501.2	"	0.2979	2902.000	411.2	"	0.007067	0.012310	236	9.7	0.3441	260.400	198.6
70	Tinned Copper	10480.000	5.33125	0.0330 ,,	0.0512 ,,	0.1863	0.47320	23/64 = 0.3594	0.91281		0.93349	253.4	10.52	14.96			0.5670	8210.000	503.6	"	0.3027	3562.000	415.2	"	0.007114	0.012371	242	9.7	0.3540	271.200	189.4
71	Tinned Copper	12860.000	6.54375	0.0269 ,,	0.0417 ,,	0.2067	0.52502	24/64 = 0.3750	0.95250		0.97318	262.2	10.92	15.36			0.5758	10080.000	506.0	"	0.3075	4372.000	419.2	"	0.007161	0.012431	248	9.7	0.3639	282.000	180.4
72	Tinned Copper	15780.000	8.03125	0.0219 ,,	0.0340 ,,	0.2294	0.58268	25/64 = 0.3906	0.99219		1.01287	271.0	11.32	15.76			0.5846	12370.000	508.4	"	0.3123	5367.000	423.2	"	0.007208	0.012491	254	9.7	0.3738	292.800	172.2
73	Tinned Copper	19370.000	9.85625	0.0178 ,,	0.0277 ,,	0.2546	0.64668	26/64 = 0.4062	1.03188		1.05256	279.8	11.72	16.16			0.5934	15180.000	510.8	"	0.3171	6586.000	427.2	"	0.007254	0.012550	260	9.7	0.3837	303.600	164.4
74	Tinned Copper	23780.000	12.09875	0.0145 ,,	0.0225 ,,	0.2826	0.71781	27/64 = 0.4219	1.07156		1.09224	288.6	12.12	16.56			0.6022	18630.000	513.2	"	0.3219	8083.000	431.2	"	0.007300	0.012608	266	9.7	0.3936	314.400	157.0
75	Tinned Copper	29180.000	14.84375	0.0118 ,,	0.0183 ,,	0.3136	0.79654	28/64 = 0.4375	1.11125		1.13193	297.4	12.52	16.96			0.6110	22870.000	515.6	"	0.3267	9920.000	435.2	"	0.007345	0.012666	272	9.7	0.4035	325.200	150.0
76	Tinned Copper	35810.000	18.21625	0.0096 ,,	0.0149 ,,	0.3480	0.88392	29/64 = 0.4531	1.15094		1.17162	306.2	12.92	17.36			0.6198	28070.000	518.0	"	0.3315	12180.000	439.2	"	0.007390	0.012723	278	9.7	0.4134	336.000	143.2
77	Tinned Copper	43940.000	22.35250	0.0078 ,,	0.0121 ,,	0.3861	0.98069	30/64 = 0.4688	1.19062		1.21130	315.0	13.32	17.76			0.6286	34450.000	520.4	"	0.3363	14950.000	443.2	"	0.007435	0.012779	284	9.7	0.4233	346.800	136.6
78	Tinned Copper	53930.000	27.43375	0.0064 ,,	0.0099 ,,	0.4284	1.08814	31/64 = 0.4844	1.23031		1.25099	323.8	13.72	18.16			0.6374	42280.000	522.8	"	0.3411	18350.000	447.2	"	0.007479	0.012835	290	9.7	0.4332	357.600	130.4
79	Tinned Copper	66190.000	33.66250	0.0052 ,,	0.0081 ,,	0.4753	1.20726	32/64 = 0.5000	1.27000		1.29068	332.6	14.12	18.56			0.6462	51900.000	525.2	"	0.3459	22530.000	451.2	"	0.007523	0.012890	296	9.7	0.4431	368.400	124.4
80	Tinned Copper	81230.000	41.31625	0.0043 ,,	0.0066 ,,	0.5272	1.33893	33/64 = 0.5156	1.30968		1.33036	341.4	14.52	18.96			0.6550	63710.000	527.6	"	0.3507	27660.000	455.2	"	0.007567	0.012945	302	9.7	0.4530	379.200	118.8
81	Tinned Copper	99710.000	50.71375	0.0035 ,,	0.0054 ,,	0.5847	1.48526	34/64 = 0.5312	1.34937		1.37005	350.2	14.92	19.36			0.6638	78210.000	530.0	"	0.3555	33960.000	459.2	"	0.007611	0.012999	308	9.7	0.4629	390.000	113.6
82	Tinned Copper	122400.000	62.25000	0.0028 ,,	0.0044 ,,	0.6485	1.64707	35/64 = 0.5469	1.38906		1.40974	359.0	15.32	19.76			0.6726	96000.000	532.4	"	0.3603	41700.000	463.2	"	0.007655	0.013053	314	9.7	0.4728	400.800	108.8
83	Tinned Copper	150300.000	76.43625	0.0023 ,,	0.0036 ,,	0.7191	1.82651	36/64 = 0.5625	1.42875		1.44943	367.8	15.72	20.16			0.6814	117900.000	534.8	"	0.3651	51200.000	467.2	"	0.007699	0.013107	320	9.7	0.4827	411.600	104.2
84	Tinned Copper	184500.000	93.84375	0.0019 ,,	0.0029 ,,	0.7975	2.02565	37/64 = 0.5781	1.46844		1.48912	376.6	16.12	20.56			0.6902	144800.000	537.2	"	0.3699	62900.000	471.2	"	0.007743	0.013161	326	9.7	0.4926	422.400	100.0
85	Tinned Copper	226500.000	115.21875	0.0015 ,,	0.0024 ,,	0.8844	2.24648	38/64 = 0.5938	1.50812		1.52880	385.4	16.52	20.96			0.6990	177800.000	539.6	"	0.3747	77200.000	475.2	"	0.007787	0.013215	332	9.7	0.5025	433.200	96.2
86	Tinned Copper	278100.000	141.46875	0.0012 ,,	0.0020 ,,	0.9806	2.49072	39/64 = 0.6094	1.54781		1.56849	394.2	16.92	21.36			0.7078	218300.000	542.0	"	0.3795	94800.000	479.2	"	0.007831	0.013268	338	9.7	0.5124	444.000	92.6
87	Tinned Copper	341500.000	173.71875	0.0010 ,,	0.0016 ,,	1.0875	2.76225	40/64 = 0.6250	1.58750		1.60818	403.0	17.32	21.76			0.7166	268000.000	544.4	"	0.3843	116400.000	483.2	"	0.007875	0.013321	344	9.7	0.5223	454.800	89.2
88	Tinned Copper	419400.000	213.33750	0.0008 ,,	0.0013 ,,	1.2060	3.06324	41/64 = 0.6406	1.62719		1.64787	411.8	17.72	22.16			0.7254	329100.000	546.8	"	0.3891	142900.000	487.2	"	0.007919	0.013374	350	9.7	0.5322	465.600	86.0
89	Tinned Copper	515200.000	262.08750	0.0006 ,,	0.0010 ,,	1.3375	3.39725	42/64 = 0.6562	1.66687		1.68755	420.6	18.12	22.56			0.7342	404200.000	549.2	"	0.3939	175500.000	491.2	"	0.007963	0.013427	356	9.7	0.5421	476.400	83.0
90	Tinned Copper	632800.000	321.87500	0.0005 ,,	0.0008 ,,	1.4831	3.76707	43/64 = 0.6719	1.70656		1.72724	429.4	18.52	22.96			0.7430	496500.000	551.6	"	0.3987	215600.000	495.2	"	0.008007	0.013480	362	9.7	0.5520	487.200	80.2
91	Tinned Copper	777400.000	395.43750	0.0004 ,,	0.0006 ,,	1.6447	4.17724	44/64 = 0.6875	1.74625		1.76693	438.2	18.92	23.36			0.7518	609900.000	554.0	"	0.4035	264900.000	499.2	"	0.008051	0.013533	368	9.7	0.5619	498.000	77.6
92	Tinned Copper	955200.000	485.81250	0.0003 ,,	0.0005 ,,	1.8236	4.63224	45/64 = 0.7031	1.78594		1.80662	447.0	19.32	23.76			0.7606	749200.000	556.4	"	0.4083	325400.000	503.2	"	0.008095	0.013586	374	9.7	0.5718	508.800	75.2
93	Tinned Copper	1173000.000	596.71875	0.0002 ,,	0.0004 ,,	2.0225	5.13715	46/64 = 0.7188	1.82562		1.84630	455.8	19.72	24.16			0.7694	920400.000	558.8	"	0.4131	399800.000	507.2	"	0.008139	0.013639	380	9.7	0.5817	519.600	72.8
94	Tinned Copper	1441000.000	732.93750	0.0002 ,,	0.0003 ,,	2.2425	5.69595	47/64 = 0.7344	1.86531		1.88599	464.6	20.12	24.56			0.7782	1130000.000	561.2	"	0.4179	491100.000	511.2	"	0.008183	0.013692	386	9.7	0.5916	530.400	70.6
95	Tinned Copper	1770000.000	900.56250	0.0001 ,,	0.0002 ,,	2.4864	6.31546	48/64 = 0.7500	1.90500		1.92568	473.4	20.52	24.96			0.7870	1388000.000	563.6	"	0.4227	603200.000	515.2	"	0.008227	0.013745	392	9.7	0.6015	541.200	68.4

The #6 Std. Sample tested now to 25° temp elevation @ 10A in water by Lab 104
103 ,, ground 101
57A ,, air 81.

The #10 Std. 62 ,, water 58.4
55 ,, ground 41.3
35 ,, air 35.6

The 10,000 cmil 325 ,, water 248.7
267 ,, ground 211.2
185 ,, air 170.0

The 200,000 600 ,, water 644.4
445 ,, ground 483.5
315 ,, air 298.

If ρ = the Thermal resistivity of the insulator
d = ,, inst. and ext. diameters of successive cents
θ = ,, temp. elevation between conductor and sheath
C = ,, ohmic res. of the cable per cm
I = ,, total current of the ext. surface per cm per C
θ₁ = ,, drop of the ext. surface.

$$\theta = \frac{2\rho}{2\pi}\left(C_0\frac{d}{d_0} + C_1\frac{d}{d_1} + \right)$$

$$\epsilon = \frac{\pi d(0.0011 + 0.00175\theta)}{}$$

$$\theta_1 = \frac{2\rho(\theta - \theta_1)}{\pi d}\left(C_0\frac{d}{d_0}\right)$$

Cable from Schenectady Works

No.	W	C₀	C	θ₁	W₁	C₀	C₁	Correction per cm	Radiation per C.	Total Emissivity	W	θ₁	W₁	C₀	C₁
49	0.3386	73800	271.7	12.5°	0.1693	36.900	192.1	0.00175	0.006924	0.00969	102	9.8	0.1328	24.920	167.4
50	0.3455	111.700	338.7	"	0.1727	37.350	239.6	"	0.005670	0.008926	116	10.4	0.1437	47.700	218.4
51	0.3611	154.700	393.3	"	0.1950	77.350	278.1	"	0.005851	0.010036	125	9.9	0.1569	61.260	249.7
52	0.3801	198.800	422.9	"	0.2058	89.400	299.0	"	0.006015	0.010940	133	9.7	0.1695	74.820	273.5
53	0.4110	248.800	452.9	"	0.2185	107.800	324.8	"	0.006103	0.011078	140	9.7	0.1821	87.360	296.1
54	0.4218	311.900	459.2	"	0.2249	135.000	344.8	"	0.006193	0.011187	146	9.7	0.1937	97.860	286.1
55	0.4322	381.400	466.5	"	0.2304	165.000	352.8	"	0.006273	0.011287	152	9.7	0.2045	107.400	274.6
56	0.4422	467.600	469.8	"	0.2356	202.400	358.2	"	0.006347	0.011381	158	9.7	0.2150	117.600	262.6
57	0.4519	573.400	472.4	"	0.2405	248.400	363.2	"	0.006417	0.011470	164	9.7	0.2252	128.400	258.0
58	0.4611	703.400	474.9	"	0.2453	304.800	367.4	"	0.006483	0.011554	170	9.7	0.2352	139.200	254.2
59	0.4701	863.400	477.2	"	0.2501	374.000	371.2	"	0.006545	0.011634	176	9.7	0.2451	150.000	250.0
60	0.4790	1059.000	479.5	"	0.2548	459.000	375.2	"	0.006604	0.011710	182	9.7	0.2550	161.400	246.6
61	0.4878	1299.000	481.9	"	0.2595	563.000	379.2	"	0.006661	0.011784	188	9.7	0.2649	172.800	243.2
62	0.4966	1594.000	484.3	"	0.2643	691.000	383.2	"	0.006716	0.011856	194	9.7	0.2748	184.200	239.8
63	0.5054	1956.000	486.8	"	0.2691	848.000	387.2	"	0.006770	0.011926	200	9.7	0.2847	195.600	236.4
64	0.5142	2401.000	489.2	"	0.2739	1041.000	391.2	"	0.006822	0.011994	206	9.7	0.2946	206.400	233.2
65	0.5230	2947.000	491.6	"	0.2787	1278.000	395.2	"	0.006873	0.012060	212	9.7	0.3045	217.200	230.0
66	0.5318	3617.000	494.0	"	0.2835	1569.000	399.2	"	0.006923	0.012124	218	9.7	0.3144	228.000	227.2
67	0.5406	4440.000	496.4	"	0.2883	1926.000	403.2	"	0.006972	0.012187	224	9.7	0.3243	238.800	217.4
68	0.5494	5450.000	498.8	"	0.2931	2364.000	407.2	"	0.007020	0.012249	230	9.7	0.3342	249.600	208.0
69	0.5582	6690.000	501.2	"	0.2979	2902.000	411.2	"	0.007067	0.012310	236	9.7	0.3441	260.400	198.6
70	0.5670	8210.000	503.6	"	0.3027	3562.000	415.2	"	0.007114	0.012371	242	9.7	0.3540	271.200	189.4
71	0.5758	10080.000	506.0	"	0.3075	4372.000	419.2	"	0.007161	0.012431	248	9.7	0.3639	282.000	180.4
72	0.5846	12370.000	508.4	"	0.3123	5367.000	423.2	"	0.007208	0.012491	254	9.7	0.3738	292.800	172.2
73	0.5934	15180.000	510.8	"	0.3171	6586.000	427.2	"	0.007254	0.012550	260	9.7	0.3837	303.600	164.4
74	0.6022	18630.000	513.2	"	0.3219	8083.000	431.2	"	0.007300	0.012608	266	9.7	0.3936	314.400	157.0
75	0.6110	22870.000	515.6	"	0.3267	9920.000	435.2	"	0.007345	0.012666	272	9.7	0.4035	325.200	150.0
76	0.6198	28070.000	518.0	"	0.3315	12180.000	439.2	"	0.007390	0.012723	278	9.7	0.4134	336.000	143.2
77	0.6286	34450.000	520.4	"	0.3363	14950.000	443.2	"	0.007435	0.012779	284	9.7	0.4233	346.800	136.6
78	0.6374	42280.000	522.8	"	0.3411	18350.000	447.2	"	0.007479	0.012835	290	9.7	0.4332	357.600	130.4
79	0.6462	51900.000	525.2	"	0.3459	22530.000	451.2	"	0.007523	0.012890	296	9.7	0.4431	368.400	124.4
80	0.6550	63710.000	527.6	"	0.3507	27660.000	455.2	"	0.007567	0.012945	302	9.7	0.4530	379.200	118.8
81	0.6638	78210.000	530.0	"	0.3555	33960.000	459.2	"	0.007611	0.012999	308	9.7	0.4629	390.000	113.6
82	0.6726	96000.000	532.4	"	0.3603	41700.000	463.2	"	0.007655	0.013053	314	9.7	0.4728	400.800	108.8
83	0.6814	117900.000	534.8	"	0.3651	51200.000	467.2	"	0.007699	0.013107	320	9.7	0.4827	411.600	104.2
84	0.6902	144800.000	537.2	"	0.3699	62900.000	471.2	"	0.007743	0.013161	326	9.7	0.4926	422.400	100.0
85	0.6990	177800.000	539.6	"	0.3747	77200.000	475.2	"	0.007787	0.013215	332	9.7	0.5025	433.200	96.2
86	0.7078	218300.000	542.0	"	0.3795	94800.000	479.2	"	0.007831	0.013268	338	9.7	0.5124	444.000	92.6
87	0.7166	268000.000	544.4	"	0.3843	116400.000	483.2	"	0.007875	0.013321	344	9.7	0.5223	454.800	89.2
88	0.7254	329100.000	546.8	"	0.3891	142900.000	487.2	"	0.007919	0.013374	350	9.7	0.5322	465.600	86.0
89	0.7342	404200.000	549.2	"	0.3939	175500.000	491.2	"	0.007963	0.013427	356	9.7	0.5421	476.400	83.0
90	0.7430	496500.000	551.6	"	0.3987	215600.000	495.2	"	0.008007	0.013480	362	9.7	0.5520	487.200	80.2
91	0.7518	609900.000	554.0	"	0.4035	264900.000	499.2	"	0.008051	0.013533	368	9.7	0.5619	498.000	77.6
92	0.7606	749200.000	556.4	"	0.4083	325400.000	503.2	"	0.008095	0.013586	374	9.7	0.5718	508.800	75.2
93	0.7694	920400.000	558.8	"	0.4131	399800.000	507.2	"	0.008139	0.013639	380	9.7	0.5817	519.600	72.8
94	0.7782	1130000.000	561.2	"	0.4179	491100.000	511.2	"	0.008183	0.013692	386	9.7	0.5916	530.400	70.6
95	0.7870	1388000.000	563.6	"	0.4227	603200.000	515.2	"	0.008227	0.013745	392	9.7	0.6015	541.200	68.4

No.	Water	Soil	Air	Water	Soil	Air	Water	Soil	Air	Water	Soil	Air	Water	Soil	Air
49	187A	129	83A	128A	91A	70A							116A	82A	58A
50	163A	115A	71A	114A	81A	70A							107A	76A	70A
51	146A	98A	72A	100A	70A	70A							98A	70A	70A
52	134A	90A	72A	92A	64A	70A							91A	64A	70A
53	124A	84A	72A	86A	60A	70A							86A	60A	70A
54	116A	80A	72A	80A	56A	70A							80A	56A	70A
55	110A	76A	72A	76A	54A	70A							76A	54A	70A
56	104A	72A	72A	72A	52A	70A							72A	52A	70A
57	100A	70A	72A	70A	50A	70A							70A	50A	70A
58	96A	68A	72A	68A	48A	70A							68A	48A	70A
59	92A	66A	72A	66A	46A	70A							66A	46A	70A
60	88A	64A	72A	64A	44A	70A							64A	44A	70A
61	86A	62A	72A	62A	42A	70A							62A	42A	70A
62	84A	60A	72A	60A	40A	70A							60A	40A	70A
63	82A	58A	72A	58A	38A	70A							58A	38A	70A
64	80A	56A	72A	56A	36A	70A							56A	36A	70A
65	78A	54A	72A	54A	34A	70A							54A	34A	70A
66	76A	52A	72A	52A	32A	70A							52A	32A	70A
67	74A	50A	72A	50A	30A	70A							50A	30A	70A
68	72A	48A	72A	48A	28A	70A							48A	28A	70A
69	70A	46A	72A	46A	26A	70A							46A	26A	70A
70	68A	44A	72A	44A	24A	70A							44A	24A	70A
71	66A	42A	72A	42A	22A	70A							42A	22A	70A
72	64A	40A	72A	40A	20A	70A							40A	20A	70A
73	62A	38A	72A	38A	18A	70A							38A	18A	70A
74	60A	36A	72A	36A	16A	70A							36A	16A	70A
75	58A	34A	72A	34A	14A	70A							34A	14A	70A
76	56A	32A	72A	32A	12A	70A							32A	12A	70A
77	54A	30A	72A	30A	10A	70A							30A	10A	70A
78	52A	28A	72A	28A	8

Test of Storage Cells by Bonet.

These cells already described, and whose tests are already recorded, were connected to a Walker photographic meter.

12th Sept.	Charge started				
13½ "	" stopped	Transfer in large meter = 0·0850 and 0·0815. Mean 0·0833 =			
14½ "	Discharge started.				
16th "	1st Discharge photographed	0·0705	0·0655	- 0·0680 =	
21st "	2nd charge.	0·137	0·1245	- 0·1308 =	
28th Oct.	2nd "	0·042	0·041	- 0·0415 -	
5th "	3rd discharge -	0·0495	0·056	- 0·0523.	
13th "	4th charge -	0·0745	0·0805	- 0·0765 -	
15th "	4th discharge -	0·055	0·063	- 0·059 -	
18th "	5th charge -	0·106	0·103	0·1045	@ 10 amp

Test of the Heating of the large Magnet represented on page 116.

27th October. Resistance 7·954 ω @ 24·6°C.

Passed a current of 5 amperes through the magnet coils, from 14·0 to 23·15 o'clock. At 22·30, the current was 5·259 amperes. Also, the P.D. on magnet was 48·87 volts = 9·292 ω and 257 watts.

By bridge, the resistance was = 9·246 ω.

The temp. of the air was 18·5°C. and the observed temperatures on the magnet were :—

65·2°C on wire
63·6°. . .
54·0°. . iron face.

The mean temp. of the surface may be taken as 64°C., an elevation of 49°C.

The surface of the magnet wound is 3750 sq.cm approximately.

. . . . copper sheet	-	2000 . .
	Total	5250 . .
Energy per sq. cm:	0·04895	
Sq. cms. per watt	20·43	

No. of Sample	Composition	Diam.	Length	Time for 1 oscillation	Set	Actual composition of metals
1	Copper with 7 to 9% tin	0·0350	7·0	1·5	0 after 1 hr	10 parts Cu + 0·8 parts Sn
2	" " 4·75% "	"	"	1·5	" " "	10 Cu + 0·5 Sn
3	Silver 5·66% copper	"	"	2·5	0·25 - 2·0	5 Ag + 0·3 Cu
4	" 16·67% "	"	"	2·2	0 "	5 " + 1·0 " Cu
5	" 13·04% Tin very little	"	"	2·0	0 - 3·3	20 " + 1·0 " Sn
6	Aluminium 3% Platinum	"	"	3·0	0 - 1·0	
7	" 1% Copper very little	"	"	2·9	0 - 1·0	
8	" 3% " "	"	"	2·45	0·2 - 1·0	
9	Phosphor-bronze from steam room	"	"	1·5	0 - 3·3	
10	White metal tube main spring	36·0	"	"	"	"
11	Paillard palladium " "					
12	Driver Lutz steel " "					
13	" " " " "					
14	Aluminium bronze wire	0·035	7·0	1·6	0·5 after 3·0	
15	Silver wire from a U.S. 10 dollar piece	"	"	1·75	0 " "	

Measurements of the Elasticity and Resistance of wires of various alloys. 136

All the wires were drawn to the diameter of 0·0335 cm., and 7 cms were mounted horizontally, held at one extremity in a brass clamp. The vertical displacement of the free end due to load applied at the 7·0 centimetre was observed.

Length cms	Diam. cms	Weight grms	Res. ω	Res. per cm. ω	Cross section sq. cms	Resistivity (c.g.s. units)	Sp. g.	Specific Volume	Wt in water	Sp. g. by water	Vol. by water
						17°C.					
38·8	0·035	0·0660	1·320 ω	0·034021	0·0009621	8·643 x10⁻⁶	6·52	0·0132	0·0768	9·348	0·092
77·4	0·018	0·1730	1·775 ω	0·02293	"	5·836 "	8·78	0·0199	0·1365	9·538	0·0165
60·5	0·019	0·1575	0·540 ω	0·008925	"	2·271 "	10·23	0·01574	0·1450	12·60	0·0125
90·7	0·018	0·2325	0·920 ω	0·010140	"	2·578 "	10·05	0·02389	0·2210		0·0115
39·5	0·023	0·1635	1·770 ω	0·044810	0·0004155	1·82 x10⁻⁶	8·75	0·01604			
32	0·030	0·0285	0·460	0·01437	0·0007069	4·515 x10⁻⁶	2·814	0·01005			
14·5	0·018	(	0·236	0·01627	(0·0002545)	4·11 x10⁻⁶					
100·5	0·018	0·223	4·725 ω	0·04702	0·0002547	1·196 x10⁻⁶	5·72	0·02587			
36·0	0·057 x 0·057	0·075	2·070 ω	0·05750	0·0020249	1·397 x10⁻⁶	3·57	0·0087148			
25·5	0·057 x 0·011	0·047	5·15 ω	0·2019	0·000164	5·370 x10⁻⁶	10·97	0·008233			
21·1	0·023 x 0·011	0·048	8·35 ω	0·320	0·000165	5·375 x10⁻⁶	10·95	0·008385			
34·4	0·022 x 0·011	0·065	10·42 ω	0·3029	0·0001815	5·89 x10⁻⁶	10·20	0·008347			
94·8	0·020	0·2565	3·946 ω	0·04162	0·0003141	1·303 x10⁻⁶	8·62	0·029779			
57·8	0·020	0·0	0·458 ω	0·007922	"	2·489 x10⁻⁶					

Seat of Standard Clark Cells

belonging to the Lamp Room. 10th October 92.

On R.B. diff. galvo. one coil 2700 ω approx. 1 B.c. to 18·2°C. 1·4331 volt = 175 d. with 100,000 ω in ckt. Total res. 103,000 ω circ. = 1·39 x10⁻⁸ γ ∴ 1° = 792 x10⁻⁸

Then a total res. of 3000 ω in one of these cells gave no discernible deflection in any pair back to back. With one #1 as standard, then #3 gave 5 div excess

2 - 12 - defect

1 - 1 - "

1 div. represents 23·82 x10⁻⁶ volt = 2·382 x10⁻⁵ volt. ∴ then #3 is in excess 1·19 x10⁻³ volt

2 - " defect 3·335 x10⁻³ "

1 - " - 2·382 x10⁻⁴ "

The resistance of then 3 + 2 = 600 ω approx

1 + 3 = 550 ω "

2 + 1 = 450 ω "

1600

800

3 = 350 ω "

2 = 250 ω "

1 = 200 ω "

$y = x \log x + B$

$1 = A \log \frac{1}{0.3859} + 1.1281 \cdot A = \frac{1}{1.1281 \log \frac{1}{0.3859}} = 1.329$

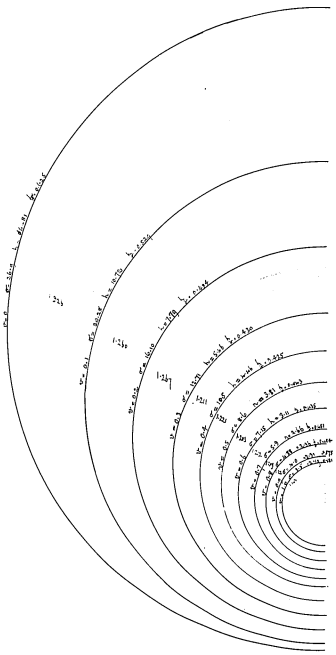
$B = 0.6 + 1.329 \log 0.6$
$= 0.5 + 0.234 = 0.734$

$y = \delta$

$\therefore \nu = -1.329 \log \nu + 0.734$

$\log \nu = \frac{0.559 - \nu}{1.329}$

Mean ratio 1.226

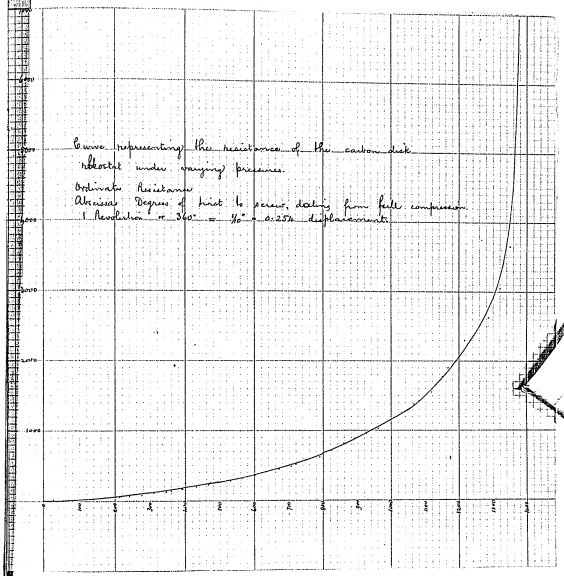


Measurements in connection with the problem of eccentric cylinders. (137)

Pt.	σ	ratio	ν	h	$\frac{h}{d}$	ν'		$\frac{\nu}{\sqrt{2g}}$	$1.557 - \frac{\nu}{\sqrt{2g}}$	σ
0	24.9	1.326	+ 0.100	16.81	0.625	+ 0.125		0	1.557	
0.1	20.28	1.260	+ 0.034	10.72	0.529	+ 0.089		1.98858	1.46642	
0.2	16.10	1.247	+ 0.041	7.79	0.484	- 0.014		0.1771	1.4653	
0.3	12.91	1.211	- 0.015	5.44	0.430	- 0.070		0.2658	1.4898	
0.4	10.5	1.221	- 0.005	4.46	0.425	- 0.075		1.3542	1.8116	
0.5	8.6	1.203	- 0.023	3.81	0.443	- 0.057		0.4424	0.9357	
0.6	7.15	1.212	- 0.014	3.11	0.435	- 0.065		0.5315	0.8579	
0.7	5.9	1.209	- 0.017	2.66	0.451	- 0.049		0.6200	0.781	
0.8	4.88	1.220	- 0.006	2.36	0.430	- 0.020		0.7088	0.7014	
0.9	4.0	1.143	- 0.083	2.31	0.576	+ 0.076		0.7972	0.6176	
1.0	3.5			2.19	0.621	+ 0.121		0.8858	0.5511	3.557
		Mean 1.226			5.511 / 5.00					

A cylinder of nickled brass 20 cms in diam: was filled with distilled water to a depth of 2.6 cms A zinc cylinder 0.952 cms in diam: was immersed vertically in this at various points and observations made with a 16,000 ω Weston voltmeter in circuit as follows:-

Dist. of centres of the cylinders apart	Dist. of centres from edge	x	β	β^2	$\sqrt{1-\beta^2}$	V	ν	$V_{\sigma=2}$	$\frac{V_{\sigma=2}}{\nu}$	ratio
-	15.0	0			1.	123.5	66.1	55.4	0.838	1.00
10.5	4.02	0.131	0.277	0.0767	0.961	124.0	67.0	55.0	0.821	0.980
8.1	6.42	0.22	0.441	0.1945	0.898	124.1	68.0	54.1	0.796	0.950
6.0	8.5	0.29	0.586	0.3431	0.870	124.1	69.5	52.6	0.757	0.903
4.45	10.05	0.35	0.693	0.4802	0.721	124.8	72.0	50.1	0.696	0.830
3.72	11.8	0.41	0.814	0.6626	0.581	123.8	75.5	48.0	0.607	0.724
1.25	13.27	0.46	0.915	0.8372	0.403	123.5	83.5	39.0	0.455	0.543


Curve representing the resistance of the carbon disk
Microtol under varying pressures.
Ordinate: Resistance
Abscissa: Degrees of twist to screw, starting from full compression.
1 Revolution = 360° = ½" = 0.250 displacements

Test of a Carbon adjustable resistance Oct. 18th

The essential parts of this instrument consist of a hard rubber vertical cylinder (1.85 ins. diam.). At the base of this is a platinum-faced brass electrode 1.75 in diam. At the top is a similar electrode at the end of a screw with 10 threads to the inch, let through the top of the instrument so as to vary at will the distance between the lower fixed and upper movable horizontal electrodes. Between them are compressed 40 disks of carbonized paper 0.020" thick and 1.75 in diam. The extreme distance between the disks is 2.99 reducible by a milled washer on the screw to 1.47". The resistances between the electrodes was measured at various distances apart, as follows:-

Angle	Res:	No of Obs.	Angle	Res	No of Obs.	Angle	Res	No of Obs.	Angle	Res
0	2.8	12	105 360°	135	23	210 720°	510	34	315 1080	1420
10 34.3°	5.0	13	115 394.3	162	24	220 752.4	580	35	325 1115	1580
20 68.6	9.0	14	125 428.6	195	25	230 788.7	620	36	335 1149	1760
30 102.9°	15.0	15	135 462.9	227	26	240.0 822.8	710	37	345 1183	1900
40 137.2	25	16	145 497.2	257	27	250 857.2	810	38	355 1217	2030
50 171.5	37	17	155 531.5	285	28	260 891.6	890	39	365 1252	2200
60 205.8	52	18	165 565.8	320	29	270 925.8	955	40	375 1286	2620
70 240.0	67	19	175 600.	360	30	280 960.0	1030	41	385 1320	3050
80 274.21	85	20	185 634.3	405	31	290 994.3	1150	42	395 1357	3650
90 308.7	105	21	195 668.6	4440	32	300 1029.	1250	43	401 1375	7150
100 343.	127	22	205 703.	495	33	310 1063.	1380	44	402 1378	7700

Test of a phosphor Receiving Coil 14th Oct: 92.

Res: @ 18°C. 97.9Ω two coils in series.
Wire #35 B&S or #36 Brs. 0.005" d.c.c. to 0.010".
Beam 100Ω @ 20°C. = 0.2934 gr. or 0.1467 gr. on each spool.
0.01834 lbs. or 0.009417 lbs. on each spool
262.2 feet = 121.1 feet - - -
Length of mean turn 2" approx.
Total turns 1953 . 727 turns - - -

Tests of Disc Ammeter Models 2 + 3.

16th Oct. 92.

Winding on one disk 100 turns of #37 B.S. 0.004145" d.i.c. & 0.010"
Resistance 18.5 ω Weight 8.17 gms. counterpoised without springs.
Weight unwound 4.75 gms. weight wound 7.47. Wire 2.72 gms.
Swung counterpoised disk from a vertical suspending wire. Period = 5.1143 secs
Loaded - - with a cylinder of fibrone - 18.25 -
Mass of fibrone cylinder 34.155 gms. Wire #35 B.S. 0.0056" d.i.c. & 0.009"
Int: rad - - 1.8125 cms
Ext - - 4.10 -
Moment of Inertia 3443 cm² gms
Moment of Inertia of disk 29.625 cm² gms
Radius of gyration 1.9 cms.

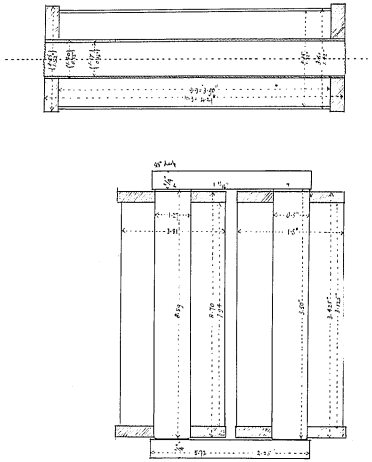
Ammeter armature 50 turns 1.64 ω 11.02 gms. without counterpoise.
Weight of wire 6.25 -
Weight - counterpoise 1.325 -
Total weight of disk 12.345 - counterpoised.
Period of counterpoised but unloaded disk 6.704 secs
- - and loaded - 19.16
Moment of inertia of counterpoised disk 47.85 cm² gms
Radius of gyration 1.97 cms.
Diameter of wire 0.0124" d.c.c. & 0.0150" # 28 B.S.

With three silver springs each about 27 cms. long 0.005" × 0.023" (0.0127 × 0.058)
The resistance of the ammeter = 1.873 ω @ 19°C. Turning 0.23 ω in springs
Pull of 0.285 gms: @ rad: of 1.65 cms = $\frac{0.470}{1.65}$ = 0.470 cm·gms for 61.25° or nearly
half load. = 0.007678 cm·gms per° = 0.96 cm·gms. at full load.

The following observations were made with the completed instrument on the 25th/26th Oct.

No. of Obs	P.D. on 20.146 ω	Amps.	Deflection of instrument	Deflection per amp.	$\frac{gms}{S}$	S	g	$\frac{gS}{Gms}$
1	0.1105	0.005492	9°	1639				
2	0.255	0.01268	20°	1577				
3	0.3805	0.01892	30°	1586				
4	0.5078	0.02525	40°	1584				
5	0.6270	0.03117	49.35°	1583				
6	0.7675	0.03816	61°	1599				
7	0.892	0.044334	70°	1579				
8	1.031	0.05126	80.5°	1571				
9	1.168	0.05806	90°	1550	2.083	1.183	1.873	0.725 ω
10	1.315	0.06537	100°	1530				
11	1.450	0.07208	108.25	1502				
12	-	-	122°					

The weight of a 1⅜ × ½ magnet is 2lbs 6½ gs. = 38.5 g.
- 3/16 - - - $\frac{24.9}{9.5}$ =
= 0.6 lbs @ 0.34 Hrs



Analysis and Data of Phonplex apparatus. Oct. 1914

1110

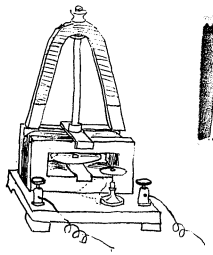
No. 1. Coil.

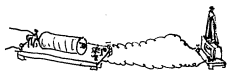
Diameter of wire	=	#23 B&S = 0.025" cotton cover. & 0.0285"
Resistance	=	7.15 ω @ 20°C.
Inductance	=	132 millihenrys.
Time Constant	=	0.01846 secs.
Mean diameter of wire	=	1"
- circ. -	=	3.1416" = 0.2618'
Number of turns per layer	=	128
Number of layers.	=	13.
Total length of wire	=	433'
- weight - -	=	0.819 lbs.
- number of turns	=	6650
Core left main wire	=	0.032" #20 B&S.
Weight of core	=	45.5 g. 0.100 lb.
Number of wires	=	111.
Length - each wire	=	4.3" = 11 cms.
Total length of iron wire	=	39.8'

Diameter of wire	=	0.0128" d.c.c. & 0.0172" # 28 B&S.
Resistance	=	75 ω on each spool. or 150 ω in all.
Mean winding diam.	=	1"
Mean circ.	=	3.14" = 0.2619'
Total no. of turns per layer	=	190
- length of wire	=	1153' on each spool 2306' in all.
- weight - -	=	0.555 lbs. - - - 1.110 lbs. -
- number - turns	=	4402 - - - 8804 - -
- - of layers	=	26. - - - 26 × 0.0172 = 0.45
- weight	=	1142 gms.

Resistance box of 5 coils

Diameter of wire	=	0.015" d.c.c. & 0.0205" #26 B&S.
Interplunge	=	0.82"
Length of spool	=	1.0"
Diameter over winding	=	0.66"
Base diameter	=	0.375"
Turns per layer	=	37
Flange diam.	=	0.75"
Number of layers	=	8.
Total number of turns	=	296
Total resistance	=	10.2 ω @ 20°C. or 2.04 ω per spool.
Length on each spool	=	50' = 250' in all.
Weight - - -	=	0.0383 lbs. or 0.1915 lbs in all.
Base of walnut wood	=	6" × 3 3/4" Base 1.1225" high × 1.5" × 5.325".





Measurement of the elastic constants of springs in wire from various alloys

Aluminium bronze wire # 14 B.W.G.

A length of 400 cms. mounted in the magnetometer with one of the vibrators gave

7	swings in	62 secs.	=	8.857 secs. per n
31n	"	300	=	9.8235 " "
15n	"	1165	=	9.8227 " "
15n	"	1331	=	9.8712 " "
26n	"	2373	=	9.8216 " "

The same vibrator loaded with a ring whose dimensions are

$R = 5.964 \div 2 = 2.982$

$r = 3.993 \div 2 = 1.9965$

$M = 167.2$ gms.

$I = \frac{M}{2}(R^2 + r^2) = 83.645\,(8.8923 + 3.984) = 83.645 \times 12.8783 = 1078.9$ cm³gm

92.2041 10.9585 82.2456

Gave

7	swings in	128 secs.	=	18.287 secs. per n
37	"	677	=	18.2162 " "
6n	"	1171.5	=	18.3046 " "

Moment of inertia of unloaded vibrator $= \frac{8.8216^2}{18.3046^2 - 8.8216^2} \times 1078.9$

$\frac{77.82}{335.06 - 77.82} = \frac{77.82}{258.24}$

$= 325.36$ cm³gm.

89.7972 0.2334 85 82.2456 0.2334 85 82.0122 3.2385

The torsional $\frac{\text{moment}}{\text{rotation}}$ of the wire $= \frac{4\pi^4 I l}{T^2 n^2} = \frac{4 \times 9.8696 \times 325.36 \times 400}{77.82} = 6602$

The wire was drawn through a sapphire draw plate 0.020 cm.

With a wire drawn through the same die, from drawn silver, the length 39 cms, there were 5 swings in 163 secs. = 32.6 secs. per n with loaded vibrator

9	swings in	293	=	32.55 secs.
26	"	849	=	32.654 "

$I = 1204.26$ cm³gm

$\mu = 39.4784 \times 1204.3 \times 39 / 1066.3 = 2027.5$

Dimensions of a galvanic tourniquet for the Meter Resistance

Internal length of coil = 3.0"

" breadth " " = 1.2"

Interflange " = 1.0" 2.54

Filled with #31 Brs. 0.0089" s.c.c.

The finished dimensions are

Mass of disk = 4.175 gms. including agate cup

Diameter " = 6.35

Thickness " = .01524 (0.006")

No. of turns in coil = 2180

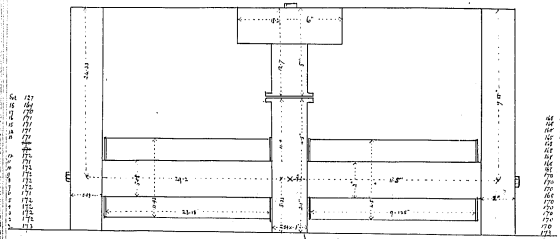
Resistance of coil = 220Ω @ 19°C.

Inductance " = 0.335 H with disk in place.

After having been brought by an small medical induction coil, with 2 cells spinning it to a speed of 160 rpm. The magnet was suddenly removed and the secondary circuit broken. The disk took 320 seconds to stop rotating and break into oscillations. Without magnetisation it might have required 8 mins. to come to rest.

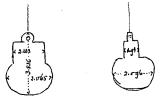
The instrument does not rotate when operated by an alternating current transformer.

Magnetic Bridge Elevation 1/4



3213 turns in 14 layers. 3213 turns in 14 layers.

Mass of disk and pointer 28 g.



Magnetic Bridge for Testing Samples of Iron and Steel.

Core diameters	= 5.08	
Cross section in core	= 20.3 sq. cms.	
Uprights	= 5.08 × 5.08 (2"×2")	
" Cross section	= 23.18	
Winding depth	= 2.54 (1")	
Interchange	= 23.18.	
Ext: cond surface on each spool	= 739.4 sq. cms.	
Winding	= 19 layers of 170 turns = 3230 turns on each spool of #19 B&S. 0.042" s.c.c. & 0.053"	
Diameter of mean turn	= 12.4·0"	
Circumference	= 12.57" = 1.05'	
Total length of wire	= 3392' on each spool.	6784' in all
" weight	= 18.13 lbs	36.26 lbs
" resistance	= 19.84 ohms @ 20°C = 22.7 @ 60°C.	39.6 @ 60°C.
Current through coil only @ 120	= 3.03 amp.	
Excitation	= 20,555 cmf turns. = 258.0 abs. or 2584 Gilb.	
Energy developed at 120 volts	= 364 watts or 4.06 sq. cms. per watt.	

Bridge areas

Diameter	7.30 and 1.55
Area	20.93 − 0.93 = 20 sq. cms.
Air gap	1/16" 0.16 cms.
Reluctance of gap	8.26 millionvolts = 0.00826

Disk diameter	2" 5.082
Winding	100 turns of #28 B&S. 0.014" d.c.c. & 0.017"

Particulars of a glass vibrator 27th Oct. 92.

A glass clapper was made having the spherical portion about 1 in diameter, surmounted by a flat square portion, and this again by a glass eye. The weight in air of this clapper was 16.4025 gms. After a little square plate of thin microscope glass had been scanned on one of its flat surfaces by canada balsam. The weight in hot water @ 20° C. was 9.132 gms.

volume 7.271 c.c.

Sp. gr. 2.256

This was suspended by a platinoid wire, and observed to make 200 period in 481 secs: or 2.405 secs per n.

The standard vibrator was mounted on the same wire and observed to make 71 swings in 1190 secs or to have a period of 16.761 secs.

$$I_1 = 1/(16.761)^2 \times (2.405)^2 \times 328.36.$$

$$\frac{5.7844}{280.9776} \times 328.36$$

$$= 6.70 \text{ cm}^3\text{gms.}$$

This clapper was suspended by a bundle composite silk fibre in a vertical glass tube 2.5 mil: diam. The length of the fibre was 22, and its diameter (owing finely) in this tube which was carefully exhausted, the periodic time was about 60 seconds. When the pointed pole of the large electromagnet was brought up to the opposite side of the glass tube, without touching it & the magnet excited, the periodic time reduced to 18 seconds.

Determination of the best winding for a disk ammeter.

Let l = the length of one turn on the disk
n = " number of turns.
a = " mean effective magnetic action radius
σ = " specific gravity of the wire
ρ = " resistivity " " " " Abs. measure
d = " diameter " " " cms.
m = " mass " " " gms.
r = " resistance " " " abs. meas.
s = " " of each spring " " "
μ = " moment of magnetic force (cm. degree)
γ = " current in the disk abs. meas.
e = " emf impressed upon the disk " "

$$r = \frac{4 l \rho n}{\pi d^2}$$

$$R = 2s + \frac{4 l \rho n}{\pi d^2} = \frac{2 s \pi d^2 + 4 l n \rho}{\pi d^2}$$

$$\gamma = e/R = \frac{e \pi d^2}{2 s \pi d^2 + 4 l n \rho}$$

$$\mu = \gamma H \frac{n}{3} \alpha = \frac{\alpha H e n \pi d^2}{6 s \pi d^2 + 12 l n \rho}$$

$$m = \frac{l n \pi d^2 \sigma}{4} \quad \therefore d^2 = \frac{4m}{l n \pi \sigma}$$

$$\therefore \mu = \frac{4 \alpha H e n \pi m}{6 s \pi 4 m + 12 l^2 n^2 \rho \sigma} = \frac{\alpha H e n m}{6 s m + 3 l^2 n^2 \rho \sigma} = \frac{\alpha e m H}{3} \Big/ \frac{n}{(2 s m + l^2 n^2 \rho \sigma)}$$

$$\frac{d\mu}{dn} = \frac{\alpha e m H}{3} \left(\frac{l^2 n^2 \rho \sigma + 2 m s - 2 n^2 l^2 \rho \sigma}{(2 s m + l^2 n^2 \rho \sigma)^2} \right)$$

For a maximum $l^2 n^2 \rho \sigma = 2 m s$

$$n = \frac{1}{l} \sqrt{\frac{2 m s}{\rho \sigma}}$$

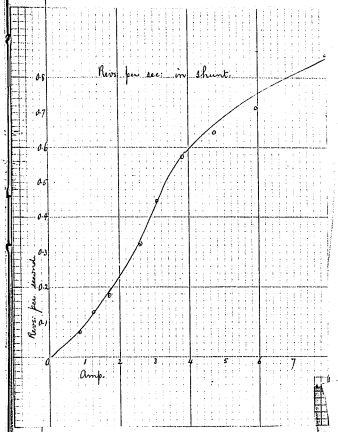
For the best shape silver springs $2s = 0.23 \times 10^7$ $m = 6.3$
$\rho = 1700$ $\sigma = 8.9$ $l = 15$

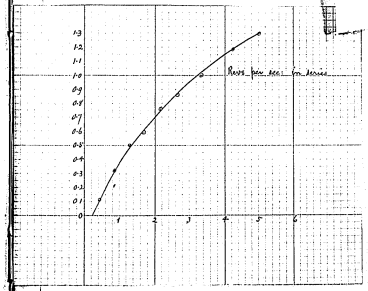
$$n = \frac{1}{15} \sqrt{\frac{1.449 \times 10^7}{1.5138 \times 10^4}} = \frac{1000}{15} \sqrt{9.58}$$

$$= \frac{3 \cdot 2 \pi 9}{15} = 21 \text{ wires.}$$

Proposed standard ratings of ammeters

0 to 0·050
0 to 0·250
0 to 0·500
0 to 1
0 to 2·5
0 to 5·0
0 to 10·0 all to 0 – 15


Resist. for sec. in shunt.
Amps.


Resist. for sec. in series

Tests of Patent-Motor-Meter whose design appears on page 132.

31st Oct: 92.

1882

Machine just completed, oiled, and connected as a shunt motor

No. of Obs.	Time	Elapsed	Revs. of armature	Secs. for rev.	Revs. for sec. of time	Lamps	Ohms	Amps.	Revs. for sec. per amp.
1	$\frac{14\cdot58\cdot13}{15\cdot00\cdot22}$	69	5	13·8	$0\cdot072\frac{46}{4876}$	2	0·168	0·8668	0·08364
2	$\frac{57\cdot13}{58\cdot31\cdot5}$	78·5	10	7·85	$0\cdot127\frac{40}{5240}$	3	0·241	1·2414	0·10224
3	$\frac{56\cdot46}{59\cdot38}$	112·	20	5·60	$0\cdot178\frac{6}{3716}$	4	0·331	1·708	0·10464
4	$\frac{59\cdot33}{16\cdot1\cdot05}$	92	30	3·06	$0\cdot326\frac{8}{2548}$	6	0·57	2·633	0·12442
5	$\frac{1\cdot23}{2\cdot40\cdot5}$	67·5	30	2·25	$0\cdot444\frac{9}{2514}$	8	0·596	3·076	0·14463
6	$\frac{3\cdot27}{5\cdot16}$	87	50	1·74	$0\cdot574\frac{7}{2682}$	10	0·74	3·818	0·15026
7	$\frac{6\cdot15}{7\cdot36}$	78	50	1·56	$0\cdot64\frac{10}{3246}$	12	0·915	4·722	0·13573
8	$\frac{8\cdot53}{10\cdot05}$	70	50	1·40	$0\cdot714\frac{3}{2828}$	15	1·158	5·975	0·11958
9	$\frac{10\cdot59\cdot5}{11\cdot2\cdot7}$	57·5	50	1·15	$0\cdot869\frac{6}{2504}$	20	1·56	8·05	0·10800
10	$\frac{13\cdot05}{14\cdot10}$	65	5	13·0	$0\cdot076\frac{9}{4522}$	2	0·178	0·892	0·08536

No. of Obs.	Time elapsed	Elapsed	Revs. of armature	Secs. for rev.	Revs. for sec. of time	Lamps	Ohms	Amps.	Revs. for sec. per amp.
1	$\frac{18\cdot52}{19\cdot04}$	92	10	9·2	0·1086	1	0·088	0·4654	0·2342
2	$\frac{20\cdot12}{1\cdot15}$	63	20	3·15	0·3175	2	0·170	0·877	0·3621
3	$\frac{22\cdot36}{23\cdot16}$	40	20	2·0	0·500	3	0·259	1·336	0·3743
4	$\frac{\cdot38}{\cdot21}$	17	10	1·7	0·5882	4	0·332	1·713	0·3433
5	$\frac{25\cdot03}{26\cdot41}$	66	50	1·32	0·7576	5	0·422	2·178	0·3678
6	$\frac{27\cdot25}{27\cdot43}$	58	50	1·16	0·8621	6	0·5703	2·633	0·3275
7	$\frac{28\cdot45}{28\cdot63}$	180	50	0·99	0·5010	8	0·650	3·354	0·3011
8	$\frac{30\cdot0}{30\cdot38}$	95	100	0·95	0·1176	10	0·820	4·232	0·2779
9	$\frac{31\cdot53}{32\cdot59}$	86	100	0·86	0·1162	10	0·820	4·232	0·2795
10	$\frac{33\cdot8}{34\cdot5}$	77	100	0·77	1·299	12	0·97	5·008	0·2595
11									
12		88	10	8·80	0·1136	1	0·085	0·438	

Res: of armature, brushes, + cords 0·210 ω @ 15°C.

" " Field coils · Right Hand 0·180ω

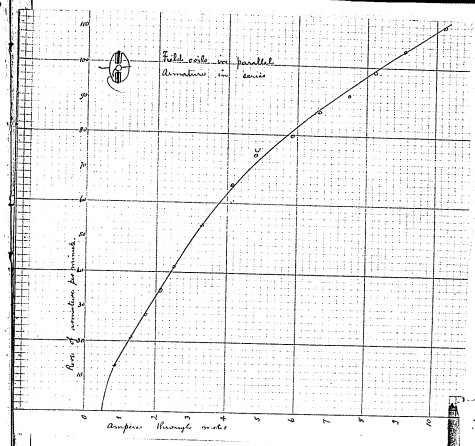
" " " Left - 0·143ω

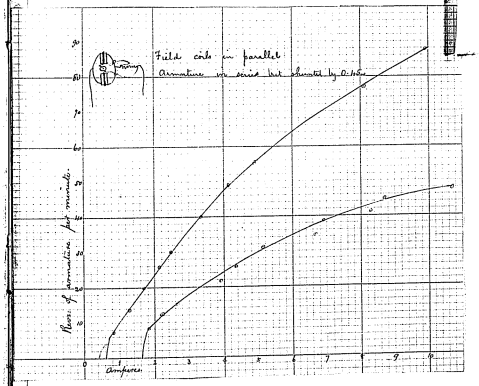
Frictions. Armature only 2·40 revs. per.

" Brushes on 10·90 " "

" Counter + - " 12·0 " "

" Fan - - " 30·0 " "


Field coils in parallel
Armature in series
Revs. of armature per minute.
Amperes through motor


Field coils in parallel
Armature in series but shunted by 0.1Ω
Revs. of armature per minute.
Amperes

Test of Motor Meter continued.

The two field coils in parallel and the armature then in series.

No. of Obs.	Time	Interval	Revs. of arm.	Secs. per rev. of arm.	Revs. of arm. per sec.	Revs. of arm. per min.	Revs. of arm. per hour	Lamps	Ohms	Amp.	Revs. per watt hour
1	$\frac{8.12.03}{84.5}$	4.5.5	10	4.55	0.2198	13.188	131.9	2	0.166	0.1586	15.12
2	$\frac{12.49}{78.31}$	57	20	2.85	0.3509	21.054	210.5	3	0.252	1.30	16.19
3	$\frac{12.25}{12.25.5}$	5.4	25	2.16	0.4630	27.78	277.8	4	0.330	1.703	16.31
4	$\frac{16.355}{171.18}$	52.5	30	1.75	0.5714	34.284	342.6	5	0.412	2.126	16.12
5	$\frac{18.524}{19.1.0}$	5.8	40	1.45	0.6897	41.382	413.8	6	0.493	2.529	16.3
6	$\frac{19.405}{20.16.5}$	5.6	50	1.12	0.8929	53.574	535.7	8	0.642	3.313	16.17
7	$\frac{21.27}{137.1}$	42	100	0.42	1.037	62.22	622.	10	0.808	4.169	14.92
8	$\frac{23.47}{24.182.5}$	81.5	100	0.815	1.227	73.620	736.2	12	0.970	5.005	14.70
9	$\frac{25.58}{26.36.5}$	90	120	0.75	1.333	79.98	799.8	14	1.132	5.852	13.67
10	$\frac{28.28.5}{29.17.5}$	69	100	0.69	1.4469	86.814	868.14	16	1.290	6.676	13.06
11	$\frac{29.46}{30.37.5}$	65.5	100	0.655	1.527	91.62	916.2	18	1.450	7.482	12.25
12	$\frac{31.23}{32.34}$	61	100	0.61	1.639	98.34	983.4	20	1.600	8.256	11.91
13	$\frac{33.26}{34.38.5}$	57.5	100	0.575	1.739	104.34	1043.4	22	1.770	9.132	11.42
14	$\frac{36.21}{37.41.5}$	55.5	100	0.535	1.869	112.14	1121.4	25	1.985	10.241	10.95

Two field coils in parallel, armature in series with a shunt across its terminals 0.445 ω in res:

No. of Obs.	Time	Interval	Revs. of arm.	Secs. per rev. of arm.	Revs. of arm. per sec.	Revs. of arm. per min.	Revs. of arm. per hour	Lamps	Ohms	Amp.	Revs. per watt hour
1	$\frac{11.10.34}{11.51}$	79	10	7.9	0.1269	7.614	76.14	2	0.1621	0.836	9.104
2	$\frac{12.48}{13.24}$	4.825	10	4.825	0.2112	12.872	128.7	3	0.241	1.244	11.15
3	$\frac{15.14}{22.4}$	150	50	3.0	0.3333	20.	200	4	0.327	1.688	11.85
4	$\frac{18.37}{20.33}$	116	50	2.32	0.4310	25.86	258.6	5	0.413	2.131	12.14
5	$\frac{21.38}{23.18}$	100	50	2.00	0.500	30.	300	6	0.475	2.451	12.24
6	$\frac{24.57}{25.53}$	75	50	1.50	0.6667	40.	400	8	0.652	3.368	11.89
7	$\frac{26.56}{27.57}$	61.5	50	1.23	0.8130	48.78	487.8	10	0.803	4.1446	11.77
8	$\frac{28.52}{30.46}$	114	100	1.14	0.8754	525.24	5252.	12	0.947	4.887	11.37
9	$\frac{31.28}{33.11}$	83	100	0.83	1.205	72.30	723.0	15	1.182	6.10	11.85
10	$\frac{33.51}{35.23}$	78	100	0.78	1.282	76.92	769.2	20	1.567	8.086	9.512
11	$\frac{36.2145}{37.33}$	68.5	100	0.685	1.460	87.6	876.	25	1.920	9.908	8.842

Test of Motor Meter for Edison Patent Unit contd; 1

Field coils in parallel, and armature also.

Nov. 1st

No. of Obs.	Times	Interval	Revs of armr	Secs per rev of armr	Revs of armr per sec	Revs of armr per min.	Revs of fan per min	Lamps	Watts	Amps.	R. per min per amp.
1	4. 42.33 / 43.78.5	74.5	10	7.45	0.1342	8.052	80.52	4	0.345	1.78	4.52
2	15. 44.31 / 45.50.5	49.5	10	4.95	0.2020	12.12	121.2	5	0.428	2.209	5.496
3	47.31 / 48.50	79	20	3.93	0.2545	15.27	152.7	7	0.516	2.663	5.7314
4	50.2 / 51	50.5	20	2.525	0.3960	23.76	237.6	9	0.752	3.896	5.556
5	52.38 / 53.37	58	25	2.32	0.4310	25.86	258.6	10	0.845	4.36	5.932
6	54.57.5 / 56.41.5	97	50	1.94	0.5155	30.93	309.3	12	0.995	5.135	6.022
7	57.36 / 59.14	85	50	1.70	0.5882	35.292	352.92	14	1.240	6.656	5.352
8	1.00 / 2.18	78	50	1.56	0.6410	38.46	384.6	16	1.340	6.912	5.564
9	3.28 / 4.41.5	73	50	1.46	0.6849	41.094	410.9	18	1.61	8.308	4.946
10	10.45 / 12.41	67	50	1.34	0.7463	44.778	447.8	20	1.69	8.72	5.135
11	13.32.5 / 15.23	63	50	1.26	0.7937	47.622	476.2	25	2.08	10.73	4.438

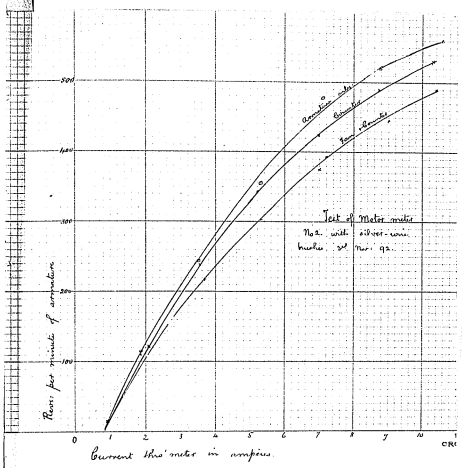
For the curve of these results see the lower chart of the preceding page.

Test of the preceding Motor-Meter with for which see Book V. p.

Both field coils in series, and the armature in shunt.

	Time	Interval secs.	Revs of armr	Secs per rev of armr	Revs of armr per sec.	Revs of armr per min.	Revs of fan per min	Lamps	Watts	Amps.	R. per min per amp.
1	10.57.18 / 11.00.16.5	177.5	1375	0.	7.746	464.76	465	22	1.95	10.06	46.2
2	11. 1.36 / 4.33	193	1375		7.126	427.562	427.5	22	1.805	9.312	45.9
3	5.29 / 8.03	209	1375		6.578	394.68	395	20	1.675	8.624	45.7
4	9.36 / 12.57	191	1100		5.76	345.6	345.5	18	1.495	7.71	44.8
5	13.33 / 17.11	218.5	1100		5.03	318	318	16	1.320	6.81	46.7
6	19.16.5 / 21.20	199	825		4.15	249	249	12	1.143	5.90	42.2
7	1.00	600"	210				210	12	1.026	5.37	39.1
8	1.00	-	167				167	10	0.833	4.30	38.8
9	-	-	123				123	8	0.655	3.38	36.4
10	-	-	83				83	6	0.51	2.63	31.5
11	-	-	63				63	4	0.342	2.17	29.0
12	-	-	31				31	4	0.335	1.73	17.9

50 teeth on worm wheel, 10 on pinion
85 - - intermediate - 10 - } 275 revs of shaft to 1 unit on dial.
100 - - unit -


Revs. per minute of armature
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
Current thro' meter in amperes
Test of Meter meter
No 2. with silver-wire
bushes. 2nd Nov. 92.

Test of Motor-Meter No. 2.

New silver wire brushes were substituted and the following measurements made (1) with the fan spindle off, armature only running, counter indicating; but fan off

(2) - - - running, counter indicating but fan off

(3) - fan and counter both at work.

No. of Obs.	Time.	Revs.	R.p.m.	Obmeh.	Lamps	Amp.	R. from pre. temp.		
1	one min.	114·2	114·2	0·180	2	4·0929			Armature only
2	"	116	116	0·365	4	1·8814			
3	"	244	244	0·680	8	3·5079			
4	"	355	355	1·030	12	5·315			
5	"	477	477	1·377	16	7·106			
6	"	520	520	1·700	20	8·772			
7	"	560	560	2·050	24	10·68			
8	"	155	155	0·182	2	2·939			Armature resistor
9	"	121	121	0·349	4	2·084			
10	"	239	239	0·685	8	3·535			
11	"	342	342	1·010	12	5·211			
12	"	374	374	1·360	16	7·018			
13	"	490	490	1·700	20	8·771			
14	"	630	630	2·000	24	10·32			
15	"	114·5	114·5	0·188	2	0·970			Armature, counter, + fan
16	"	110	110	0·360	4	1·858			
17	"	216	216	0·710	8	3·664			
18	"	302	302	1·030	12	5·315			
19	"	393	393	1·390	16	7·172			
20	"	1·345	1·345	1·720	20	8·880			
21	"	490	490	2·020	24	10·42			

Motor Meter #5 when running under test suddenly developed an irregular motion. The origin of this was finally traced to electrical trouble in the armature. A variable short-circuit was found to exist between the layers and the armature had eventually to be rewound.

$x = 42.35\ \varepsilon \qquad \sin \frac{t}{38.77}$

$-0.000\,6515\,t$

$\log 42.35 = 1.626485$

$\log 38.3 = \frac{1.583030}{0.111765}$

$\frac{T.070719}{0.311221.57}$

$\frac{T.382501.6}{2.632145.73}$

$\log 42.4 = \frac{2.632145.73}{T.700035.03}$

$x = 53.3\ \varepsilon \qquad \sin \frac{t}{31.2}$

$-0.002\,9155\,t$

$\log 53.3 = 1.726733$

$\log 20.7 = \frac{1.315877}{0.410856}$

$\frac{T.613788.81}{0.362221.27}$

$\frac{T.975808.38}{2.588195.55}$

$\log 31.3 = \frac{2.588195.55}{5.213385.03}$

Magnet unexcited

No. of Obs.	Time	Period	No. of Swings	Deflection	Amplitude
1	17.04.05			26.7	
2		36		69.05	42.35
3	04.44	0.36	1	27.1	41.95
4		36		68.7	41.6
5	5.20	0.42	2	28.5	40.2
6		36		68.3	39.8
7	5.58	1.50	3	27.8	40.5
8		37		67.7	39.9
9	6.35	2.27	4	28.2	39.5
10		40		67.65	39.45
11	7.15	3.07	5	28.3	39.35
12		38		67.2	38.9
13	7.93	3.45	6	28.55	38.65
14		37		67.1	38.55
15	8.20	4.12	7	29.0	38.1
16		37		65.8	36.8
17	8.55	4.47	8	29.0	36.9
18		36		66.4	37.4
19	9.31	5.23	9	29.2	37.2
20		37		66.2	37.0
21	10.08	6.00	10	29.5	36.7
22		36		63.4	33.9
23	.43	6.35	11	29.8	33.6
24		36		63.1	33.3
25	10.19	7.11	12	30.1	33.0
26		36		62.7	32.6
27	.53	7.45	13	30.4	32.3
28				62.7	32.3
29		$\frac{4.65}{15} = 37.77$ secs			
30					

Magnet excited

Time	Period	No. of Swings	Deflection	Amplitude
17.18.38			21.8	
		31	75.1	53.3
19.08	0.35	1	24.3	50.8
		31	72.25	47.95
19.39	1.06	2	24.6	45.65
		31	70.5	43.9
20.10	1.37	3	25.4	42.1
		33	68.2	39.8
.42	2.09	4	30.0	38.2
		31	66.5	36.5
21.13	2.40	5	31.5	35.0
		31	64.95	33.465
.44	3.11	6	32.8	32.15
		34	63.6	30.8
22.18	3.45	7	33.9	29.7
		32	62.3	28.4
.48	4.15	8	35.1	27.2
		31	61.25	26.15
23.19	4.46	9	35.9	25.35
		31	62.2	26.3
.50	5.17	10	36.75	25.45
		30	59.4	22.65
24.20	5.47	11	37.4	22.0
		28	58.7	21.3
.53	6.20	12	38.0	20.7
		$\frac{38.0}{12} = 31.66$		

Vibration of Quartz Sphere in Magnetic Field. (148)

A sphere of quartz from the Edser-Hunty collection has a mean diameter of $1.504'' = 3.820$ cms. The maximum diameter is equatorial being $1.514'' = 3.8461$ cms. The minimum diameter is near the poles and $1.498'' = 3.805$ cms.

The weight of this sphere in air is 78.2925 gms.

Imp H_2O @ 16°C $\frac{46.916}{28.3765}$ Sp. g. 2.6535

A hole has been bored in this sphere 0.25" (0.635) in diameter, and 1" (2.54) deep. The direction of this hole is not quite diametrical. The base of the is rough and unfinished.

A small cork was fitted into this hole, and the height with thread taken from the centre of the cork, which is alluded to here as the pole. The length of the suspending composite fibre was 22.5. The fine silk fibre made one turn round the sphere on a longitudinal meridian, in order to render the vibrations visible. The sphere was finally suspended in air between the equator poles of the electromagnet, which were separated by 4.15 leaving 0.165 clearance on each side of the sphere. Glass plates set vertically against the poles, acted as windows, and breaded to prevent disturbances from air currents. The sphere was set rotating about its suspension fibre with the magnet idle, and again with the magnet excited.

Magnet idle, 11 complete periods effected between 16.58.02 and 17.22.19 = 24.16 = 1456 seconds = 132.3 secs per π.

The amplitude diminished in 8 periods from 75° to 10°

When the magnet was excited, the sphere executed 7 complete periods between 17.23.58 and 17.29.48 = 890 seconds = 50 secs. per π and the amplitude diminished in the same time from 65° to 6° = 10.85

$\lambda_1 = \frac{2.3026}{10} \log 7.5 = \frac{2.3026}{12} \times 0.875016 = 0.110436 \qquad \frac{\lambda_1}{\pi} = \frac{0.110436}{66.15'} = 2.031 \times 10^{-3}$

$\lambda_2 = \frac{2.3026}{13} \log 10.83 = \frac{2.3026}{13} \times 1.034118 = 0.1833 \qquad \frac{\lambda_2}{\pi} = \frac{0.1833}{25'} = 7.33 \times 10^{-3}$

The measurement was repeated more carefully as follows on the 8th Nov. A glass rod 19 long, and 0.294 in diameter, was fastened into the wall orifice with sealing wax, and at the upper end of the rod a mirror was attached and a suspension wire of copper 32 long and 0.007 in diameter. The apparatus was shielded from air currents and observations of a scale made by telescope, the distance between mirror and scale being 1468 cm.

For the continuation of this series see p. 153.

The copper suspension wire having given way, one of Pt-Ir alloy was substituted, having a diameter of 0.0079 and a length of 38.

Description of an ammeter made by the Chloride of Silver Battery Co. 9th Nov.

This instrument consists of a rectangular coil of wire, with a pair of astatic Shombre steel needles, one within the coil, the other over it. The upper needle is supported on a jewel center, the lower is attached by a strap. A pointer is brought to a scale in front. The influence of external fields is limited by a small permanent magnet at the base, with its pole nearly closed by a bar, capable of a limited degree of motion by a screw projecting through the case of the instrument. There are two shunts one ½ the other 1/10. These are connected by rotating a notched head, and the same motion changes the scale on a boxwood shaped solid, at the same time.

The res: of the instrument is 47 ω @ 15°C, 9·12 ω, and 0·95 ω.

Analysis of a Weston Ammeter # 567 9th Nov: 92.

This instrument reads from 0 to 0·5 amp. and also from 0 to 10 amp.
Its resistance when connected with the lower scale is 0·092 ω drop 0·046 volt
" " " upper " " 0·0054 ω " 0·060 "
Its weight all complete without leather case is 5 lbs. 2 oz.
There are 214 turns of wire on the spool, in 2 layers.
The springs have the appearance of dull silver.
There are 7 spires, the external radius being 1·2 cms, Mean rad: abt 0·7
Estimated length 30·8
Breadth by calculation

		Thickness	
0·0693		0·01475	
0·0665		0·01363	
0·0658		0·01400	
0·0660		0·01300	
273	= 0·0668	0·05538	= 0·01385

Gross section 0·00425 sq/cms A/ρ = 0·000300ω for one springs = 0·000600 for both
Chord of scale = 1·329 = 53°·1'
Moment of the springs at half load = 0·1855 gms × 3·36 = 0·4552 cms-gms.
" " per degree of indication = 0·01096 cms-gms
" " at full load = 0·91 cms-gms

Resistance of the coil and springs together = 0·507ω @ 18°C.
" in circuit with the coil = 0·321ω
Total resistance of coil circuit = 0·828ω

Particulars of new model ammeter for 10 amperes 9th Nov: 92.

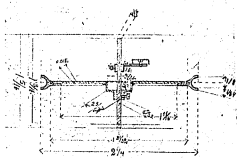
Mass of disk 13·78 gms with pointer + counterpoise
Period of vibration with a certain q.f. wire = 6·250 secs.
" " loaded with 343 cm-gms. = 18·4 "
Radius of gyration = 1·81
Springs of drawn silver = 6¾ spires. Length 9¾ Breadth. 0·0575 Thickness 0·0135" 0·01261"
Cross section = 0·007764
Winding of disk. = 25 double turns of #28 D.S.C. = section 0·0081 50 turns in all
" wire = 0·0315 D.S.C.
Resistance of wire = 0·389ω @ 15°C.
" wire + springs = 0·637ω

Moment of springs at chord 1·135 = 69°·10'

1·62 × 0·795	=	0·640 cm-gms.
2·92 × 0·205	=	0·599 "
2·13 × 0·30	=	0·639 "
1·30 × 0·485	=	0·630
		2·508
Mean		0·627 "

Winding applied = ·009264 cm-gms per ° of deviation
= 6 lengths of 7 feet each #20 BWG in parallel.
= 0·009425 × ⅞ = 0·009 83 ω
Res: of instrument = 0·01 ω approx: actually 0·017

Final. test										
by Potent.	1·22	1·93	2·96	4·10	4·75	6·03	7·12	8·09	9·04	9·48	10·28
"						5·96	7·04	8·10	9·00	9·45	10·09
by Ballistic	1·17	1·98	3·01	4·10	4·75						
Deflections	0·05	0·07	0·05	0	0	0·07	0·08	·03	0·04	6,05	9,20



Finished dimensions 6¼" × 8⅝" × 2·4" Weight 5 lbs 2½ oz.

$343 \times \frac{6.255^2}{19.4^2 - 6.255^2} = 343 \times \frac{39.125}{338.25 - 39.125} = 343 \times \frac{39.125}{299.125} = 44.92$

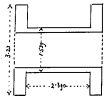
$\sqrt{\frac{44.92}{13.7}} = 3.269^{\frac{1}{2}} = 1.808$

For 10 amples the drop in the instrument between terminals was 0·475 volt
but between pressure wire 0·0160 = 0·16 volt.
Resistance of disk circuit = 1·078 ω
Current in " at load = ·1485 amp.
Res traversed by fourier = 120 · for 10 amp = 12° for amp.
Current in disk Ckt. for degree = ·0124 amp. = 0·000124 = 1·24 10^{-4} ab.
" " each wire of disk for degree = 6·27 10^{-5} ab.
Number of turns of wire in field = 25·5 average say 26.
Mean length of wire in each side = 2·0 cms
Total " " active wire = 52 cms
Mean radius of active " = 1·03 "

$\frac{H \times 52 \times 1.03 \times 6.2 \times 10^{-5}}{} = 9.648 \times 0.981$, H = 1800. = 18 minigauss

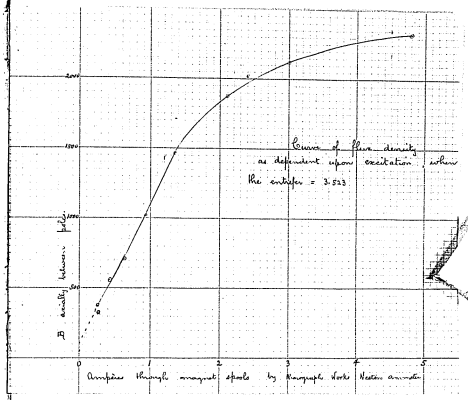
Total useful flux = 18000 = 180 kilogaussmax
Brass section of magnet = 2·96 × 1·05 = 3·0
Useful intensity in magnet = 6000 = 60 minigausses

Axial section Full size



Total no. of turns = 611
Layers = 16
Wire = # 25 B.W.G. 0.020" d.c.c. & 0.0225"
Turns per layer = 38
Spool Internal diameter = 1.539 (0.606")
External diameter over wire = 3.230 (1.272")
Mean diameter = 2.3845
Mean area = 4.24666 sq. cms.
Total area = 2798.20 sq. cms.
Inductance = 2.390 (0.941")
Breadth over all = (1.23")
Mass of spool = 7.26 gms.
Resistance = 4.16 ω @ 20°c
Inductance = 4.91 millihenrys.

Layer	Radius r	r^2	No. of turns	nr^2	Σnr^2	$\pi\Sigma nr^2$	
1	0.7959	0.63346	38		887.31	2.4496515	
2	0.8487	0.72021	39		·720	0.2697 1499	
3	0.8916	0.79495	38		·892	3.44 68014	
4	0.9344	0.87289	39		1.103	27977	
5	0.9773	0.95481	38		1.728		
6	1.0502	1.10250	39		891.753		
7	1.1030	1.21660	37		1.217		
8	1.1559	1.33630	38		890.536		
9	1.2087	1.46160	38				
10	1.2616	1.59200	38				
11	1.3144	1.72801	39				
12	1.3674	1.87000	38				
13	1.4203	2.01700	38				
14	1.4731	2.17000	38				
15	1.5260	2.32860	38				
16	1.5788	2.49250	38				
		23.35030					

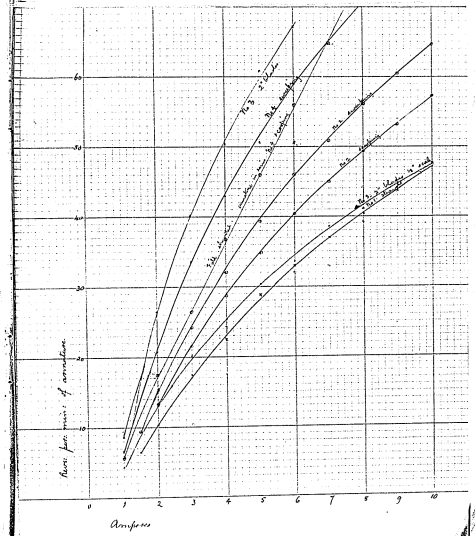


Particulars of new Field Exploring Coil Nov. 11th 92.

The strength of the field existing between the square pole pieces of the large electromagnet at the centre was measured with ballistic Galvanometer and a new exploring coil which was unwound and rewound for the purpose. The current in the spools of the large magnet was varied and its influence on the intensity of the field determined. The magnet has 2728 turns, and the exciter was 3.523 (1.358 + 1.398 ohms)

Source of E.M.F	E.M.F at temp.	Reference	Mean throw	q. per div.
1 D. cell @ 20.5°C.	1.428×10^8	10^{-5} (1°)	157.3 15 throws 1.42810^{-7}	9.078×10^{-10} 0.907×10^{-7}

No of Obs	Current thro' magnet Amps by Potom	M.M.F.	Throw	Mean Throw	Resom ext:	q.	ϕ	B	
1	0.286	981	222 223 221 218 215	220	52.50	1.997×10^{-7}	1.048×10^6	3735	
2	0.431	1478	170 166 167	167.7	5000 + 5250 ‖ 10,250	1.522×10^{-7}	1.560×10^6	5576	
3	0.62	2126	213 212 213	212.7	5000 + 5250 ‖ 10,250	1.931×10^{-7}	1.979×10^6	7074	
4	0.915	3138	205 & 207 208	206.7	10000 + 5250 ‖ 15,250	1.876×10^{-7}	2.861×10^6	1023.	
5	1.350	4629	148 151 149	149.3	25,000 + 5250 ‖ 30,250	1.385×10^{-7}	4.099×10^6	14665	
6	2.10	7200	191 191 191	191	? 25,000 + 5250 ‖ 30,250	1.734×10^{-7}	5.245×10^6	18758	
7	3.01	10,320	224 214 212 & 214	216	25,000 + 5250 ‖ 30,250	1.961×10^{-7}	5.932×10^6	21208	
8	3.84 4.50 4.76	16,460	236 236 237	236.3	25,000 + 5250 ‖ 30,250	2.145×10^{-7}	6.489×10^6	23196	
9	4.90		35 & 34 32	33.7	5250	3.060×10^{-8}	1.606×10^6	20337	Small Coil Uniform

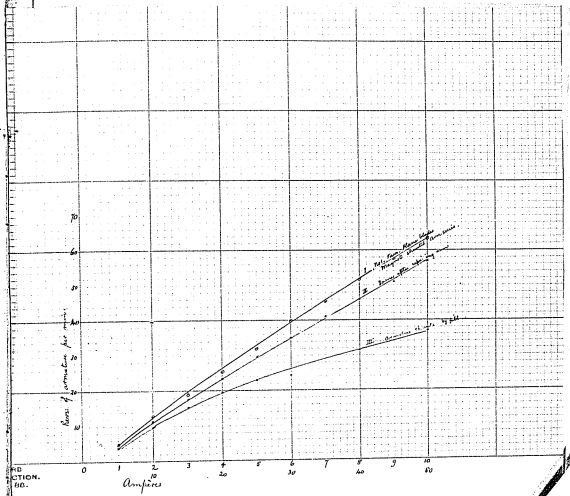

Amperes

Tests of Motor-Meter No. 5, rewound, after rewinding armatures.

The field magnets were connected in parallel, and the armatures three in parallel with the fields.

No. of Obs.	Time	C.	Revs.	Rpm.	Rpm. per amp.
Fields in parallel, armatures also in parallel, brush blades on 2 segments.	1	1'	1·5	9·4	9·4	6·27
	2	–	2·0	15·2	15·2	7·6
	3	–	3·0	24·15	24·15	8·05
	4	–	4·0	32·0	32·0	8·00
	5	–	5·0	39·3	39·3	7·86
	6	–	6·0	46·0	46·0	7·67
	7	–	7·0	50·85	50·85	7·27
	8	–	8·0	56·1	56·1	7·01
	9	–	9·0	60·5	60·5	6·72
	10	–	10·0	64·75	64·75	6·475
Fields in parallel, armatures also in parallel, brush blades on 4 segments.	1	–	1·25	absent		
	2	–	2·0	18·15	13·15	6·58
	3	–	3·0	21·5	29·5	7·17
	4	–	4·0	28·7	28·7	7·18
	5	–	5·0	34·9	34·9	6·98
	6	–	6·0	40·35	40·35	6·73
	7	–	7·0	45·0	45·0	6·43
	8	–	8·0	49·3	49·3	6·16
	9	–	9·0	53·1	53·1	5·90
	10	–	10·0	57·15	57·15	5·72
Fields in parallel, armatures also in parallel, brush blades on 4 segments.	1	–	1·25	absent		
	2	–	1·50	6·4	6·4	4·27
	3	–	2·0	10·4	10·4	5·2
	4	–	3·0	17·45	17·45	5·82
	5	–	4·0	22·8	22·8	5·70
	6	–	5·0	28·95	28·95	5·79
	7	–	6·0	33·0	33·0	5·50
	8	–	7·0	36·9	36·9	5·27
	9	–	8·0	40·14	40·14	5·05
	10	–	9·0	43·7	43·7	4·85
	11	–	10·0	47·6	47·6	4·76

No. of Obs.	Time	C.	Revs.	Rpm.	Rpm. per amp.
Fields in parallel, armatures also in parallel, No 3. with 2" Water-Blast	1	1'	8·0	8·6	8·6	8·6
	2	1'	2·0	26·45	26·45	13·2
	3	1'	3·0	40·15	40·15	13·38
	4	1'	4·0	50·45	50·45	12·61
	5	1'	5·0	60·9	60·9	12·18
	6	1'	6·0	67·25	67·25	11·21
	7	1'	7·0	74·5	74·5	10·64
	8	1'	8·0	82·15	82·15	10·27
	9	1'	9·07	88·1	88·1	9·82
	10	1'	10·0	95·2	95·2	9·52
Fields in parallel, armatures also in parallel, No 4. 4 segments.	1	1'	1·0	6·65	6·65	6·65
	2	"	2·0	20·75	20·75	10·375
	3	"	3·0	33·6	33·6	11·2
	4	"	4·0	42·95	42·95	10·72
	5	"	5·0	50·55	50·55	10·11
	6	"	6·0	57·0	57·0	9·83
	7	"	7·0	64·75	64·75	9·25
	8	"	8·0	70·5	70·5	8·81
	9	"	9·0	76·5	76·9	8·61
	10	"	10·0	83·0	83·0	8·30
Fields in parallel but shunted by 4 ohms each in series. No 4 4 segments.	1	1'	1·0	5·75	5·75	5·75
	2	"	2·0	17·35	17·35	8·68
	3	"	3·0	26·4	26·4	8·8
	4	"	4·0	36·8	36·8	9·2
	5	"	5·0	45·9	45·9	9·18
	6	"	6·0	56·0	56·0	9·33
	7	"	7·0	64·8	64·8	9·25
	8	"	8·0	72·8	72·8	9·10
	9	"	9·0	82·9	82·9	9·21
	10	"	10·0	92·25	92·25	9·23


Amperes
0
1
2
3
4
5
6
7
8
9
10

Tests of Motor Meter # 5 contd: Nov. 14th

Fields in parallel + armature shunt by 3 ohms coil. Speed by observation of revs. in minute by Weston Meter # 1

No. of Obs.	Load in amps	Time	Revs.	Revs.	Rev/amp	
1	0.9	1'	4.5	4.5	5.33	
2	2.0	"	12.9	12.9	6.45	
3	3.0	"	18.9	18.9	6.3	
4	4.0	"	25.45	25.45	6.36	
5	5.0	"	32.2	32.2	6.44	Curve # I
6	6.0	"	39.8	39.8	6.63	
7	7.0	"	45.6	45.6	6.51	
8	8.0	"	51.6	51.6	6.45	
9	9.0	"	57.45	57.45	6.38	
10	10.0	"	64.5	64.5	6.45	

Fields in parallel + armature shunt by 3 ohms coil. Speed by observation of revs. in minute by Weston Meter # 1 (Adjustment of plus lag regulating screw)

1	0.97	1'	3.95	3.95	4.0	
2	2.0	"	11.45	11.75	5.73	
3	3.0	"	17.5	17.5	5.83	
4	4.0	"	23.45	23.45	5.86	
5	5.0	"	29.7	29.7	5.94	
6	6.0	"	35.1	35.1	5.85	
7	7.0	"	41.0	41.0	5.86	Curve # II
8	8.0	"	46.0	46.0	5.75	
9	9.0	"	51.1	51.1	5.65	
10	10.0	"	56.9	56.9	5.69	

Fields in parallel armature shunt by 3 ohms coil. Speed by observation of revs. in minute by Weston Meter # 1

1	7.8	1'	~~30.1~~	~~30.1~~		
2	10.0	"	9.75	9.75	0.975	
3	15.0	"	15.15	15.15	1.01	
4	20.0	"	19.6	19.6	0.98	
5	25.0	"	23.15	23.15	0.926	
6	20.0	"	24.25	24.25	0.808	
7	40.0	"	31.7	31.7	0.793	
8	50.0	"	37.0	37.0	0.740	Curve No III in red
9						
10						

Vibration of Quartz sphere in magnetic field (cont. from p. 148. Nov. 1924) (163)

Unwashed	Field H = 3100			C = 1.1 — K = 12500				C = 1.76 — H = 11750				C = 4.43 — H = 2300			
Swing Pos.	Time	Elong.	Amp.		Time	Elong.	Amp.	τ	Time	Elong.	Amp.	τ	Time	Elong.	Amp.
	θ = 0°				θ = 0°				θ = 0°				θ = 0°		
0	15-01.11	30.2		0	17-00.65	56.2		0	11-53.37	71.8		0	16-00.27	68.2	
1	"	29.6			05.09	55.1			54.15	71.3			01.28	67.8	
2	"	29.0			09.40	53.9			"	70.8			02.29	67.4	
3	"	28.4			13.69	52.7			54.92	70.2			03.29	66.9	
4	"	27.8			17.96	51.5			"	69.7			04.29	66.4	
5	9-03	27.2			22.21	50.3			55.68	69.2			05.29	65.9	
6	"	26.6			26.45	49.1			"	68.7			06.29	65.4	
7	"	26.0			30.67	47.9			56.43	68.2			07.29	64.9	
8	"	25.4			34.87	46.7			"	67.7			08.29	64.4	
9	10-10	24.8			39.05	45.5			57.18	67.2			09.29	63.9	
10	"	24.2			43.21	44.3			"	66.7			10.29	63.4	
11	"	23.6			47.35	43.1			57.93	66.2			11.29	62.9	
12	"	23.0			51.47	41.9			"	65.7			12.29	62.4	
13	"	22.4			55.57	40.7			58.68	65.2			13.29	61.9	
14	"	21.8			59.65	39.5			"	64.7			14.29	61.4	
15	"	21.2			03.71	38.3			59.43	64.2			15.29	60.9	
16	"	20.6			07.75	37.1			"	63.7			16.29	60.4	
17	"	20.0			11.77	35.9			60.18	63.2			17.29	59.9	
18	"	19.4			15.77	34.7			"	62.7			18.29	59.4	
19	"	18.8			19.75	33.5			60.93	62.2			19.29	58.9	
20	"	18.2			23.71	32.3			"	61.7			20.29	58.4	
21	"	17.6			27.65	31.1			61.68	61.2			21.29	57.9	
22	"	17.0			31.57	29.9			"	60.7			22.29	57.4	
23	"	16.4			35.47	28.7			62.43	60.2			23.29	56.9	
24	"	15.8			39.35	27.5			"	59.7			24.29	56.4	
25	"	15.2			43.21	26.3			63.18	59.2			25.29	55.9	
26	"	14.6			47.05	25.1			"	58.7			26.29	55.4	
27	"	14.0			50.87	23.9			63.93	58.2			27.29	54.9	
28	"	13.4			54.67	22.7			"	57.7			28.29	54.4	
29	"	12.8			58.45	21.5			64.68	57.2			29.29	53.9	
30	"	12.2			02.21	20.3			"	56.7			30.29	53.4	
31	"	11.6			05.95	19.1			65.43	56.2			31.29	52.9	
32	"	11.0			09.67	17.9			"	55.7			32.29	52.4	
33	"	10.4			13.37	16.7			66.18	55.2			33.29	51.9	
34	"	9.8			17.05	15.5			"	54.7			34.29	51.4	
35	"	9.2			20.71	14.3			66.93	53.2			35.29	50.9	
36	"	8.6			24.35	13.1			"	52.7			36.29	50.4	
37	"	8.0			27.97	11.9			67.68	51.2			37.29	49.9	
38	"	7.4			31.57	10.7			"	50.7			38.29	49.4	
39	"	6.8			35.15	9.5			68.43	49.2			39.29	48.9	
40	"	6.2			38.71	8.3			"	48.7			40.29	48.4	
41	"	5.6			42.25	7.1			69.18	47.2			41.29	47.9	
42	"	5.0			45.77	5.9			"	46.7			42.29	47.4	
43	"	4.4			49.27	4.7			69.93	45.2			43.29	46.9	
44	"	3.8			52.75	3.5			"	44.7			44.29	46.4	
45	"	3.2			56.21	2.3			70.68	43.2			45.29	45.9	
46	"	2.6			59.65	1.1			"	42.7			46.29	45.4	
47	"	2.0			03.07	0.1			71.43	41.2			47.29	44.9	
48	"	1.4			06.47	0.9			"	40.7			48.29	44.4	
49	"	0.8			09.85	2.1			72.18	39.2			49.29	43.9	
50	"	0.2			13.21	3.3			"	38.7			50.29	43.4	
51	"	0.4			16.55	4.5			72.93	37.2			51.29	42.9	
52	"	1.0			19.87	5.7			"	36.7			52.29	42.4	
53	"	1.6			23.17	6.9			73.68	35.2			53.29	41.9	
54	"	2.2			26.45	8.1			"	34.7			54.29	41.4	
55	"	2.8			29.71	9.3			74.43	33.2			55.29	40.9	
56	"	3.4			32.95	10.5			"	32.7			56.29	40.4	
57	"	4.0			36.17	11.7			75.18	31.2			57.29	39.9	
58	"	4.6			39.37	12.9			"	30.7			58.29	39.4	
59	"	5.2			42.55	14.1			75.93	29.2			59.29	38.9	
60	"	5.8			45.71	15.3			"	28.7			60.29	38.4	
61	"	6.4			48.85	16.5			76.68	27.2			61.29	37.9	
62	"	7.0			51.97	17.7			"	26.7			62.29	37.4	
63	"	7.6			55.07	18.9			77.43	25.2			63.29	36.9	
64	"	8.2			58.15	20.1			"	24.7			64.29	36.4	
65	"	8.8			01.21	21.3			78.18	23.2			65.29	35.9	
66	"	9.4			04.25	22.5			"	22.7			66.29	35.4	
67	"	10.0			07.27	23.7			78.93	21.2			67.29	34.9	
68	"	10.6			10.27	24.9			"	20.7			68.29	34.4	
69	"	11.2			13.25	26.1			79.68	19.2			69.29	33.9	
70	"	11.8			16.21	27.3			"	18.7			70.29	33.4	
71	"	12.4			19.15	28.5			80.43	17.2			71.29	32.9	
72	"	13.0			22.07	29.7			"	16.7			72.29	32.4	
73	"	13.6			24.97	30.9			81.18	15.2			73.29	31.9	
74	"	14.2			27.85	32.1			"	14.7			74.29	31.4	
75	"	14.8			30.71	33.3			81.93	13.2			75.29	30.9	
76	"	15.4			33.55	34.5			"	12.7			76.29	30.4	
77	"	16.0			36.37	35.7			82.68	11.2			77.29	29.9	
78	"	16.6			39.17	36.9			"	10.7			78.29	29.4	
79	"	17.2			41.95	38.1			83.43	9.2			79.29	28.9	
80	"	17.8			44.71	39.3			"	8.7			80.29	28.4	
81	"	18.4			47.45	40.5			84.18	7.2			81.29	27.9	
82	"	19.0			50.17	41.7			"	6.7			82.29	27.4	
83	"	19.6			52.87	42.9			84.93	5.2			83.29	26.9	
84	"	20.2			55.55	44.1			"	4.7			84.29	26.4	
85	"	20.8			58.21	45.3			85.68	3.2			85.29	25.9	
86	"	21.4			00.85	46.5			"	2.7			86.29	25.4	
87	"	22.0			03.47	47.7			86.43	1.2			87.29	24.9	
88	"	22.6			06.07	48.9			"	0.7			88.29	24.4	
89	"	23.2			08.65	50.1			87.18	0.2			89.29	23.9	
90	"	23.8			11.21	51.3			"	1.2			90.29	23.4	
91	"	24.4			13.75	52.5			87.93	2.2			91.29	22.9	
92	"	25.0			16.27	53.7			"	3.7			92.29	22.4	
93	"	25.6			18.77	54.9			88.68	4.2			93.29	21.9	
94	"	26.2			21.25	56.1			"	5.7			94.29	21.4	
95	"	26.8			23.71	57.3			89.43	6.2			95.29	20.9	
96	"	27.4			26.15	58.5			"	7.7			96.29	20.4	
97	"	28.0			28.57	59.7			90.18	8.2			97.29	19.9	
98	"	28.6			30.97	60.9			"	9.7			98.29	19.4	
99	"	29.2			33.35	62.1			90.93	10.2			99.29	18.9	
100	"	29.8			35.71	63.3			"	11.7			100.29	18.4	
101	"	30.4			38.05	64.5			91.68	12.2			101.29	17.9	
102	"	31.0			40.37	65.7			"	13.7			102.29	17.4	
103	"	31.6			42.67	66.9			92.43	14.2			103.29	16.9	
104	"	32.2			44.95	68.1			"	15.7			104.29	16.4	
105	"	32.8			47.21	69.3			93.18	16.2			105.29	15.9	
106	"	33.4			49.45	70.5			"	17.7			106.29	15.4	
107	"	34.0			51.67	71.7			93.93	18.2			107.29	14.9	
108	"	34.6			53.87	72.9			"	19.7			108.29	14.4	
109	"	35.2			56.05	74.1			94.68	20.2			109.29	13.9	
110	"	35.8			58.21	75.3			"	21.7			110.29	13.4	
111	"	36.4			00.35	76.5			95.43	22.2			111.29	12.9	
112	"	37.0			02.47	77.7			"	23.7			112.29	12.4	
113	"	37.6			04.57	78.9			96.18	24.2			113.29	11.9	
114	"	38.2			06.65	80.1			"	25.7			114.29	11.4	
115	"	38.8			08.71	81.3			96.93	26.2			115.29	10.9	
116	"	39.4			10.75	82.5			"	27.7			116.29	10.4	
117	"	40.0			12.77	83.7			97.68	28.2			117.29	9.9	
118	"	40.6			14.77	84.9			"	29.7			118.29	9.4	
119	"	41.2			16.75	86.1			98.43	30.2			119.29	8.9	
120	"	41.8			18.71	87.3			"	31.7			120.29	8.4	
121	"	42.4			20.65	88.5			99.18	32.2			121.29	7.9	
122	"	43.0			22.57	89.7			"	33.7			122.29	7.4	
123	"	43.6			24.47	90.9			99.93	34.2			123.29	6.9	
124	"	44.2			26.35	92.1			"	35.7			124.29	6.4	
125	"	44.8			28.21	93.3			100.68	36.2			125.29	5.9	
126	"	45.4			30.05	94.5			"	37.7			126.29	5.4	
127	"	46.0			31.87	95.7			101.43	38.2			127.29	4.9	
128	"	46.6			33.67	96.9			"	39.7			128.29	4.4	
129	"	47.2			35.45	98.1			102.18	40.2			129.29	3.9	
130	"	47.8			37.21	99.3			"	41.7			130.29	3.4	
131	"	48.4			38.95	100.5			102.93	42.2			131.29	2.9	
132	"	49.0			40.67	101.7			"	43.7			132.29	2.4	
133	"	49.6			42.37	102.9			103.68	44.2			133.29	1.9	
134	"	50.2			44.05	104.1			"	45.7			134.29	1.4	
135	"	50.8			45.71	105.3			104.43	46.2			135.29	0.9	
136	"	51.4			47.35	106.5			"	47.7			136.29	0.4	
137	"	52.0			48.97	107.7			105.18	48.2			137.29	0.1	
138	"	52.6			50.57	108.9			"	49.7			138.29	0.6	
139	"	53.2			52.15	110.1			105.93	50.2			139.29	1.1	
140	"	53.8			53.71	111.3			"	51.7			140.29	1.6	
141	"	54.4			55.25	112.5			106.68	52.2			141.29	2.1	
142	"	55.0			56.77	113.7			"	53.7			142.29	2.6	
143	"	55.6			58.27	114.9			107.43	54.2			143.29	3.1	
144	"	56.2			59.75	116.1			"	55.7			144.29	3.6	
145	"	56.8			01.21	117.3			108.18	56.2			145.29	4.1	
146	"	57.4			02.65	118.5			"	57.7			146.29	4.6	
147	"	58.0			04.07	119.7			108.93	58.2			147.29	5.1	
148	"	58.6			05.47	120.9			"	59.7			148.29	5.6	
149	"	59.2			06.85	122.1			109.68	60.2			149.29	6.1	
150	"	59.8			08.21	123.3			"	61.7			150.29	6.6	
151	"	60.4			09.55	124.5			110.43	62.2			151.29	7.1	
152	"	61.0			10.87	125.7			"	63.7			152.29	7.6	
153	"	61.6			12.17	126.9			111.18	64.2			153.29	8.1	
154	"	62.2			13.45	128.1			"	65.7			154.29	8.6	
155	"	62.8			14.71	129.3			111.93	66.2			155.29	9.1	
156	"	63.4			15.95	130.5			"	67.7			156.29	9.6	
157	"	64.0			17.17	131.7			112.68	68.2			157.29	10.1	
158	"	64.6			18.37	132.9			"	69.7			158.29	10.6	
159	"	65.2			19.55	134.1			113.43	70.2			159.29	11.1	
160	"	65.8			20.71	135.3			"	71.7			160.29	11.6	
161	"	66.4			21.85	136.5			114.18	72.2			161.29	12.1	
162	"	67.0			22.97	137.7			"	73.7			162.29	12.6	
163	"	67.6			24.07	138.9			114.93	74.2			163.29	13.1	
164	"	68.2			25.15	140.1			"	75.7			164.29	13.6	
165	"	68.8			26.21	141.3			115.68	76.2			165.29	14.1	
166	"	69.4			27.25	142.5			"	77.7			166.29	14.6	
167	"	70.0			28.27	143.7			116.43	78.2			167.29	15.1	
168	"	70.6			29.27	144.9			"	79.7			168.29	15.6	
169	"	71.2			30.25	146.1			117.18	80.2			169.29	16.1	
170	"	71.8			31.21	147.3			"	81.7			170.29	16.6	
171	"	72.4			32.15	148.5			117.93	82.2			171.29	17.1	
172	"	73.0			33.07	149.7			"	83.7			172.29	17.6	
173	"	73.6			33.97	150.9			118.68	84.2			173.29	18.1	
174	"	74.2			34.85	152.1			"	85.7			174.29	18.6	
175	"	74.8			35.71	153.3			119.43	86.2			175.29	19.1	
176	"	75.4			36.55	154.5			"	87.7			176.29	19.6	
177	"	76.0			37.37	155.7			120.18	88.2			177.29	20.1	
178	"	76.6			38.17	156.9			"	89.7			178.29	20.6	
179	"	77.2			38.95	158.1			120.93	90.2			179.29	21.1	
180	"	77.8			39.71	159.3			"	91.7			180.29	21.6	
181	"	78.4			40.45	160.5			121.68	92.2			181.29	22.1	
182	"	79.0			41.17	161.7			"	93.7			182.29	22.6	
183	"	79.6			41.87	162.9			122.43	94.2			183.29	23.1	
184	"	80.2			42.55	164.1			"	95.7			184.29	23.6	
185	"	80.8			43.21	165.3			123.18	96.2			185.29	24.1	
186	"	81.4			43.85	166.5			"	97.7			186.29	24.6	
187	"	82.0			44.47	167.7			123.93	98.2			187.29	25.1	
188	"	82.6			45.07	168.9			"	99.7			188.29	25.6	
189	"	83.2			45.65	170.1			124.68	100.2			189.29	26.1	
190	"	83.8			46.21	171.3			"	101.7			190.29	26.6	
191	"	84.4			46.75	172.5			125.43	102.2			191.29	27.1	
192	"	85.0			47.27	173.7			"	103.7			192.29	27.6	
193	"	85.6			47.77	174.9			126.18	104.2			193.29	28.1	
194	"	86.2			48.25	176.1			"	105.7			194.29	28.6	
195	"	86.8			48.71	177.3			126.93	106.2			195.29	29.1	
196	"	87.4			49.15	178.5			"	107.7			196.29	29.6	
197	"	88.0			49.57	179.7			127.68	108.2			197.29	30.1	
198	"	88.6			49.97	180.9			"	109.7			198.29	30.6	
199	"	89.2			50.35	182.1			128.43	110.2			199.29	31.1	
200	"	89.8			50.71	183.3			"	111.7			200.29	31.6	
201	"	90.4			51.05	184.5			129.18	112.2			201.29	32.1	
202	"	91.0			51.37	185.7			"	113.7			202.29	32.6	
203	"	91.6			51.67	186.9			129.93	114.2			203.29	33.1	
204	"	92.2			51.95	188.1			"	115.7			204.29	33.6	
205	"	92.8			52.21	189.3			130.68	116.2			205.29	34.1	
206	"	93.4			52.45	190.5			"	117.7			206.29	34.6	
207	"	94.0			52.67	191.7			131.43	118.2			207.29	35.1	
208	"	94.6			52.87	192.9			"	119.7			208.29	35.6	
209	"	95.2			53.05	194.1			132.18	120.2			209.29	36.1	
210	"	95.8			53.21	195.3			"	121.7			210.29	36.6	
211	"	96.4			53.35	196.5			132.93	122.2			211.29	37.1	
212	"	97.0			53.47	197.7			"	123.7			212.29	37.6	
213	"	97.6			53.57	198.9			133.68	124.2			213.29	38.1	
214	"	98.2			53.65	200.1			"	125.7			214.29	38.6	
215	"	98.8			53.71	201.3			134.43	126.2			215.29	39.1	
216	"	99.4			53.75	202.5			"	127.7			216.29	39.6	
217	"	100.0			53.77	203.7			135.18	128.2			217.29	40.1	
218	"	100.6			53.77	204.9			"	129.7			218.29	40.6	
219	"	101.2			53.75	206.1			135.93	130.2			219.29	41.1	
220	"	101.8			53.71	207.3			"	131.7			220.29	41.6	
221	"	102.4			53.65	208.5			136.68	132.2			221.29	42.1	
222	"	103.0			53.57	209.7			"	133.7			222.29	42.6	
223	"	103.6			53.47	210.9			137.43	134.2			223.29	43.1	
224	"	104.2			53.35	212.1			"	135.7			224.29	43.6	
225	"	104.8			53.21	213.3			138.18	136.2			225.29	44.1	
226	"	105.4			53.05	214.5			"	137.7			226.29	44.6	
227	"	106.0			52.87	215.7			138.93	138.2			227.29	45.1	
228	"	106.6			52.67	216.9			"	139.7			228.29	45.6	
229	"	107.2			52.45	218.1			139.68	140.2			229.29	46.1	
230	"	107.8			52.21	219.3			"	141.7			230.29	46.6	
231	"	108.4			51.95	220.5			140.43	142.2			231.29	47.1	
232	"	109.0			51.67	221.7			"	143.7			232.29	47.6	
233	"	109.6			51.37	222.9			141.18	144.2			233.29	48.1	
234	"	110.2			51.05	224.1			"	145.7			234.29	48.6	
235	"	110.8			50.71	225.3			141.93	146.2			235.29	49.1	
236	"	111.4			50.35	226.5			"	147.7			236.29	49.6	
237	"	112.0			49.97	227.7			142.68	148.2			237.29	50.1	
238	"	112.6			49.57	228.9			"	149.7			238.29	50.6	
239	"	113.2			49.15	230.1			143.43	150.2			239.29	51.1	
240	"	113.8			48.71	231.3			"	151.7			240.29	51.6	
241	"	114.4			48.25	232.5			144.18	152.2			241.29	52.1	
242	"	115.0			47.77	233.7			"	153.7			242.29	52.6	
243	"	115.6			47.27	234.9			144.93	154.2			243.29	53.1	
244	"	116.2			46.75	236.1			"	155.7			244.29	53.6	
245	"	116.8			46.21	237.3			145.68	156.2			245.29	54.1	
246	"	117.4			45.65	238.5			"	157.7			246.29	54.6	
247	"	118.0			45.07	239.7			146.43	158.2			247.29	55.1	
248	"	118.6			44.47	240.9			"	159.7			248.29	55.6	
249	"	119.2			43.85	242.1			147.18	160.2			249.29	56.1	
250	"	119.8			43.21	243.3			"	161.7			250.29	56.6	
251	"	120.4			42.55	244.5			147.93	162.2			251.29	57.1	
252	"	121.0			41.87	245.7			"	163.7			252.29	57.6	
253	"	121.6			41.17	246.9			148.68	164.2			253.29	58.1	
254	"	122.2			40.45	248.1			"	165.7			254.29	58.6	
255	"	122.8			39.71	249.3			149.43	166.2			255.29	59.1	
256	"	123.4			38.95	250.5			"	167.7			256.29	59.6	
257	"	124.0			38.17	251.7			150.18	168.2			257.29	60.1	
258	"	124.6			37.37	252.9			"	169.7			258.29	60.6	
259	"	125.2			36.55	254.1			150.93	170.2			259.29	61.1	
260	"	125.8			35.71	255.3			"	171.7			260.29	61.6	
261	"	126.4			34.85	256.5			151.68	172.2			261.29	62.1	
262	"	127.0			33.97	257.7			"	173.7			262.29	62.6	
263	"	127.6			33.07	258.9			152.43	174.2			263.29	63.1	
264	"	128.2			32.15	260.1			"	175.7			264.29	63.6	
265	"	128.8			31.21	261.3			153.18	176.2			265.29	64.1	
266	"	129.4			30.25	262.5			"	177.7			266.29	64.6	
267	"	130.0			29.27	263.7			153.93	178.2			267.29	65.1	
268	"	130.6			28.27	264.9			"	179.7			268.29	65.6	
269	"	131.2			27.25	266.1			154.68	180.2			269.29	66.1	
270	"	131.8			26.21	267.3			"	181.7			270.29	66.6	
271	"	132.4			25.15	268.5			155.43	182.2			271.29	67.1	
272	"	133.0			24.07	269.7			"	183.7			272.29	67.6	
273	"	133.6			22.97	270.9			156.18	184.2			273.29	68.1	
274	"	134.2			21.85	272.1			"	185.7			274.29	68.6	
275	"	134.8			20.71	273.3			156.93	186.2			275.29	69.1	
276	"	135.4			19.55	274.5			"	187.7			276.29	69.6	
277	"	136.0			18.37	275.7			157.68	188.2			277.29	70.1	
278	"	136.6			17.17	276.9			"	189.7			278.29	70.6	
279	"	137.2			15.95	278.1			158.43	190.2			279.29	71.1	
280	"	137.8			14.71	279.3			"	191.7			280.29	71.6	
281	"	138.4			13.45	280.5			159.18	192.2			281.29	72.1	
282	"	139.0			12.17	281.7			"	193.7			282.29	72.6	
283	"	139.6			10.87	282.9			159.93	194.2			283.29	73.1	
284	"	140.2			09.55	284.1			"	195.7			284.29	73.6	
285	"	140.8			08.21	285.

Test of Pilo Box Model Edison Fan Motor 16th Nov. (1881)

Connected motor by belt to an Edison 6-polemachine motor, and separately excited the field, measuring the terminal P.D.

No. of Obs.	Amp. in Coil	MMF	Rotation	Rfield	E.M.F.	E.M.F. / n	Φ				
1	0.5		3051	50.9	0.832	0.01635	16,900				
2	1.0		3051	50.9	1.060	0.02082	13,880				
3	1.43		3131	52.2	1.285	0.02461	16,410				
4	1.88		3186	53.1	1.443	0.02717	18,110				
5	2.35		2970	49.5	1.533	0.03097	20,650				
6	2.78		2835	47.25	1.631	0.03452	23,020				
7	3.10		2781	46.35	1.695	0.03657	24,380				
8	3.62		2646	44.1	1.877	0.04257	28,380				
9	4.15		2646	44.1	1.933	0.04383	29,220				
10											

$\frac{48.0}{29.3} = \frac{1.6812412}{1.4668436}$

$\log = \overline{0}.2163976$

$= \overline{1}.3331711$

$\times 2.7063108$

$\overline{2}.4394819$ = 0.0091505

$\overline{0}.3622187$

$\overline{2}.4086913$ 0.0081832

$\frac{62.5}{10.6} \cdot \frac{1.7958754}{1.0263839}$

0.6294915

$3\,12$

$\overline{1}.7929823$

2.4411826

$\overline{3}.3084797$ .0020174

0.3622187

$\overline{3}.6706984$ 0.0047443

$\frac{37.25}{13.9} \cdot \frac{1.5711269}{1.1431741}$

0.4312472

$\overline{2}.6341161$

3623187

$\overline{1}.9964974$

$\log 197$ 2.2971406

3.7251005 = 0.0053101

$\frac{46.25}{31.8} \cdot \frac{1.6669987}{1.5024471}$

0.1645516

$\overline{1}.2163976$

3623187

$\overline{1}.5787163$

$\log 386$ 2.5863343

3.0550209 .0011272

On the oscillatory damping of non-conducting spheres in a magnetic field. contd. from p. 150

The next sphere tried was composed of plaster of Paris, weighing 26.992 gms. Its minimum diameter was 3.546, and its maximum 3.662, making a mean radius of $\frac{3.554}{2}$ = 1.777. This was attached by sealing wax to a glass stem 19.8 long and 2.38 in diameter. A mirror was attached by beeswax to the upper part of the stem, and a suspension wire of Pt-Ir 0.0079 diam. & 35.0 long. Dist. from scale to mirror 148

In unexcited field, this sphere executed 45 v in 619 secs. = 13.752 secs.
The amplitudes at 17.22.36 were 48.0 $\frac{22.7}{26.05}\ \frac{71.0}{22.7}\ \frac{23.1}{23.3}$ = 48.3

The corrected amplitude = 48.0
The observed amplitude at 17.32.47.5 = 29.3 practically correct.
Equation of series $\theta = \Theta\,\varepsilon^{-0.0008872t}\sin\left(\frac{2\pi t}{13.752}\right)$

With a current in the magnet coils of 2.186 amp. corresponding to B = 1900,
the sphere completed 27 periods in 311 secs. = 11.63 secs. per v
The amplitudes at 9.30.9.5 were 62.2 (corrected)
" " 9.35.21.5 " 14.6
Equation of series $\theta = \Theta\,\varepsilon^{-0.0066758t}\sin\left(\frac{2\pi t}{11.63}\right)$

With a current in the magnet coils of 4.26 amp. corresponding to B = 2200
The sphere completed 28 periods in 193 secs. = 9.192 secs. per v
The amplitudes at 11.14.17 were 37.25 (corrected)
" 11.17.24 " 13.80
Equation of series $\theta = \Theta\,\varepsilon^{-0.0083101t}\sin\left(\frac{2\pi t}{9.192}\right)$

Again with unexcited field as check
The sphere completed 25 periods in 342.5 secs. = 13.72 secs. per v
The amplitudes at 12.22.22.5 were 46.95 (corrected)
" 21.05.5 " 31.8
Equation of series $\theta = \Theta\,\varepsilon^{-0.0011326t}\sin\left(\frac{2\pi t}{13.72}\right)$

The next sphere was a glass bulb whose dimensions are as follows:-

Ext. Equatorial diameter	Max: 3.758	Min 3.704	Mean 3.728	3.72 - 1.86
" Polar "	3.729	3.693	2.711	
From lower pole to top of neck	4.27			

Mass. 3.722 gms. Contents 25.889 c.c. From which int r = 1.935

Calculated mean Thickness = 0.025

This globe was secured by a cork to a glass stem 19.8 long and 0.15 diam.
The whole system was suspended by a fine copper wire long & in diam.
In an unexcited field, the amplitude globe made one period in 18.25 secs.
8 v in the secs. The amplitudes diminished from 29.2 to 5.6 in 96 secs.
Equation of series $\theta = \Theta\,\varepsilon^{-}\sin\left(\frac{2\pi t}{18.25}\right)$

In the fully excited field, the globe executed 8 v in 6.22 secs = 15.56 secs per v and the amplitudes diminished from 79.60 to 25.60 in 1145 secs.
Equation of series $\theta = \Theta\,\varepsilon^{-}\sin\left(\frac{2\pi t}{15.56}\right)$

The globe was now tightly filled with dried flowers of sulphur (S) and tested with the same suspension. In unexcited and neutral field, the globe made 12 v in 506 secs = 42.2 secs. per v. Also
The amplitudes diminished from 72.2 (Corrected) to 20.6 in 485 secs.
Equation of series $\theta = \Theta\,\varepsilon^{-}\sin\left(\frac{2\pi t}{42.2}\right)$

In the fully excited field (B = 2300) there were evident signs of magnetic influence which torsion being necessary to restore zero. The globe made 16 v in 141 secs. = 8.819 secs. The amplitudes diminished from 21.3 to 5.0 in 136.6 secs.
Equation of series $\theta = \Theta\,\varepsilon^{-}\sin\left(\frac{2\pi t}{8.819}\right)$

Tests made on McKenna Weed Meter Nov. 22nd 32.

At Lyons T.H. Works. Meter Dept. Four McKenna meters were under trial. Much difficulty had been experienced in obtaining a regular and agglomerate deposit of mercury in the tube, and Mr McKenna employed a glass rod with which the column was stirred in order to make it coalesce. This resulted in a reduction of about 0.4" in the column length in one case.

One meter was taken to the testing room, and first connected up so that the shunt was out of circuit, and the meter bottle was in direct circuit with a milliammeter. A D'Arsonval galvanometer with a high res: added was connected round the cell at the same time to observe the pressure.

Millivolts thro. cell	Deflection on D'Arsonval	Res. in ckt. incl. 22Ω	Reduced to 1 div. in mV.	Volts on cell	Actual Res. of cell	Drop.	η		
0.00922 1	75	3008	0.000122	0.009156	1.56Ω 1.59Ω	0.000156	0.000909		
0.01964 2	82			0.010165		0.000312	0.000852		
0.02946 3	90			0.011278		0.000468	0.000810		
0.03928 4	99			0.012406		0.000624	0.000782		
0.04910 5	109			0.013548		0.000780	0.000768		
0.05892 6	120			0.014704		0.000936	0.000768		
0.06874 7	131			0.015860		0.001092	0.000772		
0.07856 8	142			0.017017		0.001248	0.000769		
0.08838 9	153			0.018173		0.001404	0.000769		
0.09822 10	164			0.019329		0.0156	0.000769		

0.0066 volt on D'Arsonval ckt. gives 1.65 divs. ∴ 1 div = 0.000142 — 0.002309
0.012 " " " " " 3 — 0.000143 — 0.002315
0.028 " " " " " 7 — 0.000142 — 0.002315
0.024 " " " " " 172 — 0.000139.5 — 0.00156

Took another series reaching higher. The results do not seem reliable

Time in cell Minutes	Gms. Cu SO4	Res. in ckt	Volts of 1 div	Volts on cell	Depth of D'Arsonval	Res.	Drop	η
	3.908	3008	0.000133	0.0156	36	1.56Ω	0.0051 0.0057	0.0955 0.0886
0.001	3.911							
0 2	7.816			0.014569	145		0.0122 0.0114	0.00837 0.00858
3	11.734			0.021469	565		0.0183 0.021	0.00817 0.00847
4	15.652			0.02498	69		0.02004 0.0225	0.00748 0.00788
5	19.569			0.03295	83		0.0305 0.035	0.00890 0.00855
6	23.250			0.042444	98		0.0366 0.043	0.00956 0.00944
7	27.336			0.049480	118		0.0427 0.049	0.00864 0.00880
8	31.246			0.057760	133		0.0488 0.055	0.00882 0.00960
9	35.173			0.066822	152		0.0579 0.063	0.00782 0.00952
10	39.08			0.075236	172		0.0610 0.070	0.00836 0.00936

23.45 / 6 = 3.908 + 0.982 = 3.838

7236
1950
5286

Tests of McKenna Meter contd.

The meter was connected as in the practical mode of operation, with a milliamperter of 7.2 Ω. (shunted by 6-) in the cells circuit. An ammeter was connected in the main ckt.

Run No.	Amp.	Time	Eff. η	Drop	Drop × 2.442	Amp.	η	Time	Amp.	Eff. η
						10.0 / 9.0 / 8.0	$\frac{1}{7.25} \times 10^{-3}$ / 8.16			$\times 10^{-3}$
1	8.5	0.08	0.8005	0.0231	0.05640				8.5	8.32
2	1.0	0.10	0.0799	0.02616	0.1164	7.5	6.82		1.0	0.81
3	1.5	0.15	0.08134	0.03783	0.1677	7.0	6.35		1.5	1.31
10	2.0	0.2	0.08141	0.05287	0.2254	6.5	5.91		2.0	1.80
5	2.5	0.25	0.08237	0.06263	0.2799	6.0	5.41		2.5	2.24
6	3.0	0.3	0.08280	0.07140	0.3305	5.5	4.99		3.0	2.68
7	3.5	0.35	0.08304	0.08694	0.3878	5.0	4.53		3.5	3.17
8	4.0	0.4	0.08370	0.09775	0.4367	4.5	4.08		4.0	3.60
9	4.5	0.45	0.08420	0.1110	0.4957	4.0	3.56		4.5	4.07
10	5.0	0.50	0.08446	0.1231	0.5495	3.5	3.08		5.0	4.55
11	5.5	0.55	0.08515	0.1361	0.6077	3.0	2.62		5.5	
12	6.0	0.60	0.08554	0.1484	0.6625	2.5	2.19		6.0	
13	6.5	0.65	0.08600	0.1596	0.7125	2.0	1.71		6.5	
14	7.0	0.7	0.08641	0.1707	0.7622	1.5	1.26		7.0	
15	7.5	0.75	0.08649	0.1825	0.8148	1.0	0.80		7.5	
16	8.0	0.8	0.08737	0.1928	0.870	0.5	0.32		8.0	
	9.0 / 10.0		550 / 553							

log 77.5 1.890776
32.25 1.508839
38.247 1.582747
3.622187
1.960960
2.352128
225 2.352128 0.003491

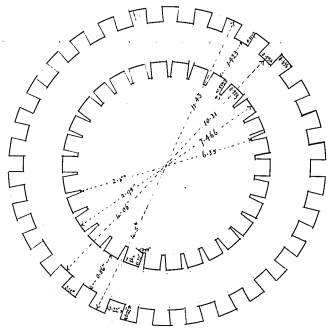
20. 1.30103
5.85 0.767156
0.536947 1.574031
0.362187
1.211784
127.5 2.105102
3.316886 0.020851

Experiments on the Oscillatory damping of Non Conducting Spheres cont: from p 155

The next spheroid experimented upon was of paraffin wax, prepared by melting this wax into a glass globe, and breaking off the glass shell when cool. The mass of this spheroid = 26.0 grms. The equatorial diam: = 3.792 mm = 3.736 mm + 3.764 mean. Polar diam: 3.987. The same suspension was employed as in the last case.

In an unexcited field this spheroid made 6 w in 226 secs = 37.6 Amplitude 77.8 mm to 92.25 mm in 225 secs. $\theta = \theta_0 e^{-0.00391 t} \sin\left(\frac{\pi t}{37.6}\right)$

In the fully excited field the spheroid made 16 w in 1165 = 36.25 Amplitude 20.0 to 8.85 in 127.5 secs. $\theta = \theta_0 e^{-0.00839 t} \sin\left(\frac{\pi t}{36.25}\right)$



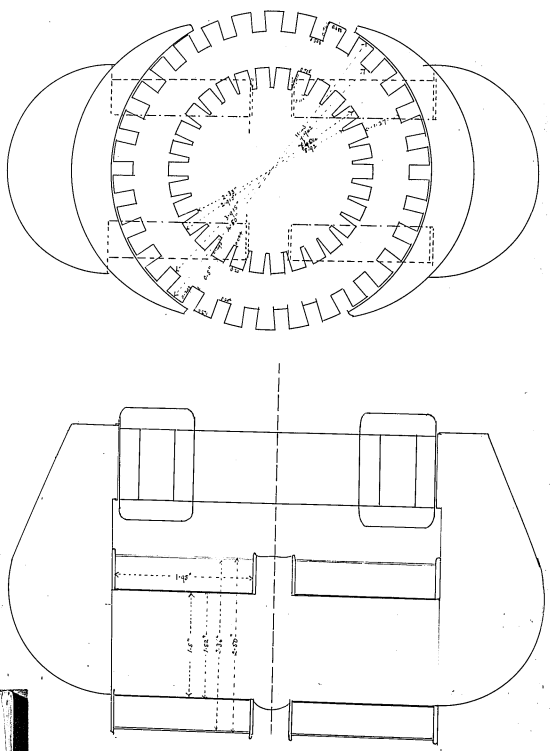
Electromagnetic Design for a Phonograph Motor. (157)

Type		Bipolar ~~shunt wound~~, gramme ring armature with teeth.
Speed		600 rpm = 10 rps.
Battery		3 Edison Lalande cells. Total EMF 2 volts
Drop in Battery	=	(0.05 × 3) × 3 = 0.45 volt
" " leads	=	0.10 × 3 = 0.3
P.D. at M.T.	=	1.25 volts.
E.M.F. of motor	=	1.2 "
Useful Flux	=	90,000 c.g.s.
Armature dimensions Ext. diam	=	4.5" (11.43)
" Int. "	=	2.5" (6.35)
Breadth of teeth	=	0.25" 0.638
Depth of groove	=	0.22" × 0.22" 0.559 × 0.559
Depth of armature	=	1.0" 2.54
Cross section of do.	=	3.97 sq. ins. allowing 90% = 3.57 sq. ins. available
B in armature	=	14,950
" " teeth	=	6,250.
Number of wires	=	120 in all, 10 in each groove.
Winding	=	11 in 89/32" 0.083" d.c.c. b 0.094"
Length of each turn	=	4.5" 0.375
Total length of wire	=	45'
" resistance	=	0.066 ω
" " of armature	=	0.0165 ω.
Drop in motor	=	0.05 volt.
Ends for	=	0.03125" (1/32") 0.08
Polar surface	=	22 sq. cms. effective.
Reluctance in air	=	0.08/11 = 0.00728
Total estimated rels	=	0.009
M.M.F. for 90,000	=	810 = 648 amp turns.
Total flux in magnet	=	1.5 × 90,000 = 135,000.
Gross section of core	=	16,875 sq. cms. @ B = 8,000
Diameter	=	4.635 cms. = 1.825"

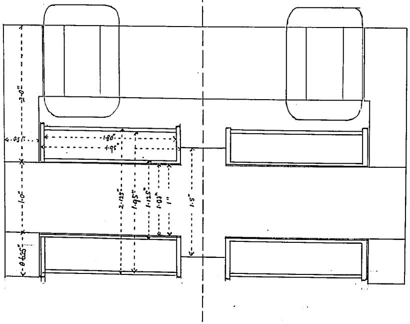
Electromagnetic Design of Phonograph Motor

Type = Shunt wound bipolar gramme ring with teeth.
Speed = 600 rpm = 10 rps.
Battery = 3 Edison-Lalande cells = 2 volts total EMF.
Drop in battery (3 × 0.05) × 5 = 0.75 volt
" " leads = 0.18 × 3 = 0.20
P.D. at terminals = 1.25 volts.
Current = 3 amp. estimated.
Power absorbed = 3.75 watts " .
Flux = 66.670 C.G.S. lines. (0.66 millimaxwell)
No. of wires = 180, 6 in each groove.
E.M.F. of motor = 1.2 volts.

Armature dimensions
Ext. diameter = 4.5" (11.43)
Int. " = 2.33" (5.92)
Breadth of body = 1.0" (2.54)
No. of teeth = 30
Breadth of teeth = 0.271" (0.688) 0.015" internal
Breadth of groove = 0.20" (0.508)
Depth of groove = 0.293" (0.744)
Breadth of core = 0.5" (1.27)
Cross section " " = 3.225 sq.inches 95% = 3.064 sq.ins.
B in core = 10,880. In teeth. 5000. (50 kilogausses)
Body insulation = 0.01"
Winding = 3 layers of 2 turns in each groove # 15 SWG = #13 B+S 0.072"
d.c.c. b 0.086":



Same Armature in Wrought Iron Field.
Spools slipped on.

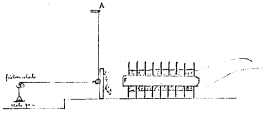


Electromagnetic Design of Phonograph Motor

Type = Shunt wound bipolar gramme ring with teeth.
Speed = 600 rpm = 10 r.p.s.
Battery = 3 Edison-Lalande cells = 2 volts total EMF.
Drop in battery (3 × 0.05) × 3 = 0.45 volt
" leads = 0.10 × 3 = 0.30
P.D. at terminals = 1.25 volts.
Current = 3 amp. estimated.
Power absorbed = 3.75 watts " .
Flux = 66.670 C.G.S. lines. (0.66 milliweber)
No. of wires = 180, 6 in each groove.
EMF. of motor = 1.2 volts.

Armature dimensions
Ext. diameter = 4.5" (11.43)
Int. " = 2.33" (5.92)
Breadth of body = 1.0" (2.54)
No. of teeth = 30
Breadth of teeth = 0.271" (0.688) 0.043" internal
Breadth of grooves = 0.20" (0.508)
Depth of grooves = 0.293" (0.744)
Breadth of core = 0.5" (1.27)
Cross section " " = 3.225 sq. cms. 95% = 3.064 sq. cms.
B in core = 10,880. In teeth. 5000. (50 microgauss)
Body insulation = 0.01"
Winding = 3 layers of 2 turns in each groove # 15 BWG = # 13 BrS 0.072" d.c.c. to 0.086".
Length of mean turn = 4.1" = 34'
Total length of wire = 61.2'
" " " " = 0.122 ω.
Mean arm. res. = 0.031 ω.
" drop in arm = 0.08 volt.
Weight of arm. wire = 0.961 lb.
Interfer. Clearance = 0.015" 0.038
Arm. Polar surface = 17.2 sq. cms.
Air reluctance = 0.038/17.2 = 0.0023 × 2 = 0.0045
Total estimated rel. = 0.0075 = 7.5 megoersteds.
M.M.F. needed = 3700 Gilbs = 300 amp-turns. say ~~1000~~.
Current in field = 0.33 amp.
Turns on " = 900
" " each spool = 450.
Cross section of core = 11.4
B in " = 8,770 (cast iron)
Flux " " = 100,000
Diam of " = 4 cms. = 1.5".
Mean turn = 0.5'
Winding of field = 10.0 layers of 45 turns each #20 B.W.G. 0.035" s.c.c. 0.042" 425 turns in all. on each spool.
Depth " winding = 0.42"
Length " wire = 425'
Weight " " = 1.57 lbs.
Resistance " " = 3.58 ω @ 20°C.
Energy " " = 0.4 watt.
Mass of iron in arm = 2.25 lbs. 1014 gms.
" " copper " " = 1.0 "
" " iron " field = 6.0 2730 "
" " copper " " = 1.6 "

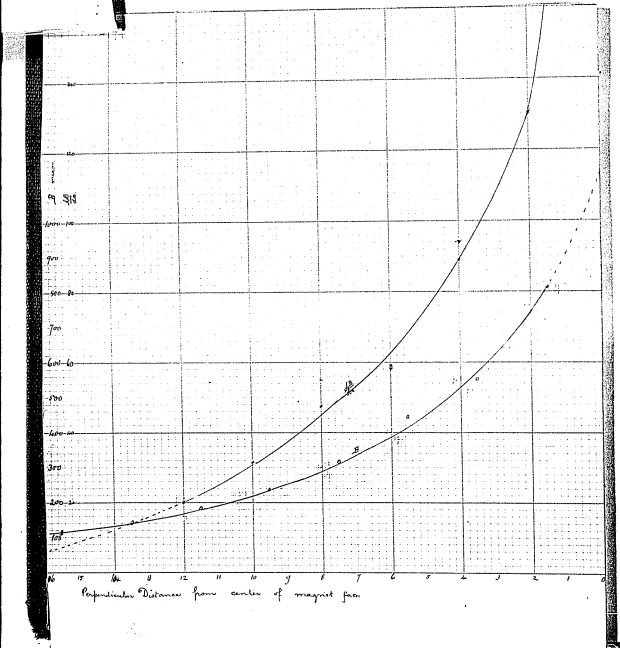
With wrought iron field magnet
Core diam = 1.0" = 2.54
Cross section = 0.785" 5.07 sq. cms.
With 20% leakage B = 16,000 ϕ = 80,000
Spool diameter Int. = 1.125"
Ext = 2.125"
Interflange = 1.80"
Winding = 1.25 lbs. of #21 B.W.G. = #20 B.S. 0.032" s.c.c. to 0.039" in 10 layers of 44 turns each = 440 turns on each spool = 880 turns in all.
Total length = 400'
" resistance = 4.0 ω @ 20°C.



$0.637^3 = 0.2585$

$\frac{4\pi}{3} = 4.1888$

$\frac{4\pi r^3}{3} = 1.083$



Measurements of Magnetic Force upon an iron sphere. 3rd Dec. 92 (161)

A sphere of iron 1·274 in diam., nearly uniform), weighing 8·5 grms. was supported by a silk thread 35" long from a wooden support. From a small brass hook in the ball, another silk thread ran over delicate frictionless pulleys and supported on scale pans weighing 0·475 grms. A zinc plate stood as a non-magnetic barrier, and when the horizontal thread was slack, the sphere was set to just touch it, hanging vertically from A, the magnet being inverted. A current of 6·1 amps was then passed through the magnet, and the pulls necessary to just dislodge the sphere noted, with the distances of the sphere from F.

The flux was also determined by setting the coil of page 150 at various distances from F, making and breaking the magnet circuit, and determining the effect upon the ballistic galvo.

Mag. Obs.	Current in magnet	Dist. of centre of sphere from F	Wt. carried in scale pans	Total weight	Pull degrees	B	ΔB	BB'	ratio $\frac{BB'}{P}$	$B\dot{B}r^2$
1	6·1 amp.	2·1275	27	27·475	26950	710 685	124 118	88914088	3·247	29,900
2		3·075	22·5	22·975	22,520	615 590	105 100	64,870500	2·8644	15,250
3		3·625	19·0	19·475	19,105	560 520	96 90	53,760000	2·8114	12,330
4		4·225	12·0	12·475	12,240	470 435	78 75	36660000	2·995	8,780
5		5·675	8·3	8·775	8,608	400 370	65 62	26,000000	3·021	5,930
6		6·625	6·20	6·975	6,848	360 310	57 56	20,520000	3·134	4,488
7		7·675	4·3	4·775	4,688	310 280	49 46	15,190000	3·244	2,650
8		8·325	3·2	3·675	3,605	275 255	42·5 40	11,690000	3·243	
9		9·195	2·4	2·875	2,821	245 180	36 38	8820000	3·127	
10		10·175	1·65	2·125	2,084	218 150	32 30	6,976 4500	3·348	
11		11·195	1·05	1·525	1,496	195 120	24 22	4,679 2400	2·987	
12		12·325	0·470	1·175	1,153	196 105	19 20	3,020 2100	2·637	
13		13·325	0·400	0·875	858	180 92	16·5 15	2,030 1380	2·366	
14		14·175	0·20	0·675	662	130 82	12. 13	1,560 1066	2·357	
15		15·575	0·0	0·475	466	115 70	7. 9	,805 630	1·727	
16		15·125	0·1	0·575	564	120 75	8·5 10	1,020 750	1·808	

EMF	Resistance	ϕ	Mean Throw	ϕ from obs.
1 El. elt @ 18°C	1 Ω			
$1{\cdot}4307 \times 10^8$	10^{-9}	$1{\cdot}4307 \times 10^{-1}$	126·4	$1{\cdot}132 \times 10^{-1}$

Dist. of centre from F	R. in set	R of crt	Throw	ϕ	Φ	B
1·55	10,000	12,280	132.	(149×10^{-7})	$2{\cdot}272 \times 10^{-6}$	812
3·55	"	"	95	$1{\cdot}075$ "	$1{\cdot}635$ "	584·4
5·55	0	52.10	20·5	$2{\cdot}383$ "	$1{\cdot}242$ "	443·9
7·55	0	"	15·5	$1{\cdot}715$ "	$8{\cdot}938 \times 10^{-5}$	319·4
9·55	0	"	11.	$1{\cdot}268$ "	$6{\cdot}606$ "	236·1
11·55	0	"	8.	$0{\cdot}9736$ "	$5{\cdot}073$ "	181·3
13·55	0	"	6?	$0{\cdot}7584$ "	$3{\cdot}952$ "	141·2
15·55	0	"	5·5	$0{\cdot}617$ "	$3{\cdot}215$ "	114·9

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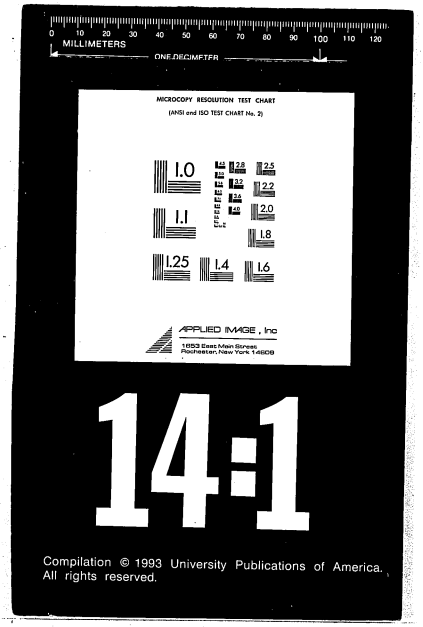

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